

BOLINAS LAGOON ECOSYSTEM RESTORATION

WATER RESOURCES APPENDIX

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1 Introduction

The goal of the Bolinas Lagoon Restoration Project is to restore ecosystem function, structure, and dynamic processes that have been degraded over time. Previous studies have shown that the lagoon experiences above-normal sedimentation rates, which reduces the tidal prism and increases the probability of inlet closure. Although lagoon systems and shallow water estuaries progress from fully functional tidal systems to meadows over the course of geologic time, it has been hypothesized that this process in Bolinas is interrupted by seismic activity, resulting in a drop of the lagoon bottom elevation and channel realignment.

In order to develop a solution to the above-normal sedimentation rate that has contributed to reduced ecosystem levels in the lagoon, data collection was completed to determine lagoon conditions from 1960 to 1998. Based on lagoon conditions in 1998 and future trends in lagoon morphology, two alternative plans were developed for lagoon ecosystem restoration. In order to develop the NER and LPP plans, the lagoon was broken up into 10 individual components. Each component was further reduced to three types of habitat levels: upland, subtidal, and intertidal. The tidal prisms and water volumes of each component were evaluated under *without project* and *with project* conditions from 1968 to 2058. These components were then organized into 12 different alternative plans from which the NER and LPP were selected. The effects of the alternative plans on lagoon tidal prism and water exchange were evaluated and verified with the use of a computer model by an independent specialist.

2 Terminology and Definitions

Typical Spring Tide: This was defined as the average spring diurnal tide for all spring tides during 1998. This resulted in a high tide of 3.15 ft National Geodetic Vertical Datum (NGVD) and a low tide of -3.45 ft (NGVD). It was calculated for only one year instead of nineteen years. It is assumed that the spring tide is similar in other years. This “standardized tide” was defined since several key parameters and calculations required spring tide elevations. Since this is not normally defined on tidal benchmark stations it was calculated in this report.

Typical Neap Tide: This was defined as the average neap diurnal tide for all neap tides during 1998 and was calculated for the same reasons and using the same methodology as the Typical Spring Tide. It was found that for a Typical Neap Ocean Tide that the high water elevation was 2.25 ft NGVD and the low water elevation was -2.05 ft NGVD.

Inlet Cross-Section Area: The cross sectional area of the inlet at its narrowest point.

Lagoon Volume: The volume in the lagoon below a prescribed elevation.

Potential Tidal Prism: The volume of water that would enter and exit the lagoon if the elevations within the lagoon matched the ocean elevations, while the water surface rises and falls uniformly.

Effective Tidal Prism: The actual volume of water entering and exiting the lagoon during the diurnal portion of a tidal cycle. Flow alterations stemming from inlet size, friction within the lagoon, wind forcing, etc. causes the effective tidal prism to be less than the potential tidal prism.

Surface Area: The area of the water surface at a given elevation within the lagoon.

Water Surface Elevation Ranges: The tidal ranges (diurnal - high to low) that the lagoon experiences. Although the lagoon's water surface was not uniform, each location within the lagoon experienced similar maximum and minimum elevations (Philip Williams and Associates (PWA) 1999).

3 Past, Present, and Future Lagoon Physics

Bolinas Lagoon is located on the northern California coastline, in Marin County, approximately 15 miles north of San Francisco (Figure 1). The lagoon is approximately 1,110-acres in size and is bisected by the northern section of the San Andreas Graben fault. In the lagoon interior, sediments released from Pine Gulch Creek, the largest tributary drainage, contributed to the formation the lagoon's two dominant intertidal features. Pine Gulch Creek delta is a tributary feature located at the outfall of Pine Gulch Creek. Kent Island, a roughly triangular land mass located just landward of the inlet, was likely established initially as an inlet flood shoal (see Figure 2). The island size increased over time due to the added contributions of Pine Gulch Creek sediments (Kamman 2001).

A sand-spit, generated by east to west long-shore currents, separates the lagoon from the Pacific Ocean. The spit controls and focuses tidal exchange through a narrow inlet in the southwestern corner of the lagoon. In turn, the location of the inlet is fixed between the rocky shoreline to the west and the stabilized sand spit. While its location is fairly stable in location, the inlet geometry remains highly dynamic. Ebb and flood tidal bars form both inside and outside the inlet. The size and locations of these features varies with changes in the magnitude of wave energy and tidal discharge. Just outside the inlet to the north, the Bolinas Bluffs rise steeply to an elevation of over 200 feet and preclude northern migration of the inlet. Duxbury Reef is the submerged extension of the rocky coastline and extends southeast of the lagoon. Duxbury Reef shelters the inlet from littoral sediments and on-shore wave energy, which if unobstructed, would increase the likelihood of inlet closure due to the onshore transport of littoral sands (Kamman 2001).



Figure 1 Bolinas Lagoon

The majority of the lagoon is publicly owned and managed as part of both the Marin County Open Space District, and the Gulf of the Farallones National Marine Sanctuary. The surrounding 16.8 square-mile watershed contains a mixture of publicly and privately owned lands. The 7.8 square-mile Pine Gulch Creek drainage dominates the northwestern shore of the lagoon. Local rock consists of both Merced Formation and Monterey Shale, more erodible materials than the adjacent Franciscan Formation found along the south and eastern shore of the lagoon. The size and composition of the drainage produce the dominant sediment load in the lagoon. This is evidenced by size of the Pine Gulch Creek delta and Kent Island features. Highway 1 runs along the northeastern side of the lagoon. Landward of the highway, nine small (less than one square mile), steeply sloped drainages originate from Bolinas Ridge at an elevation of 1500 ft. Culverts are typically used to convey discharges from these drainages to the lagoon. The sediment contribution from these drainages is comparatively smaller than that seen northeaster drainages, and sediment conveyance from these watersheds is hindered by the culverts along Highway (Kamman 2001). Figures 5 and 6 show the present condition of the lagoon.

3.1 Sediment Source – Historical Review

The Bolinas Lagoon Management Plan of 1996 (BLMP) and the Watershed Study of 2001 provided a summary of past studies such as Ritter (1970), Rountree (1973), Bergquist (1978), and Bergquist and Wahrhaftig (1993). These reports concluded that activities such as logging, grazing, road construction, fires, and stream channelization contributed to above normal sedimentation rates in the lagoon.

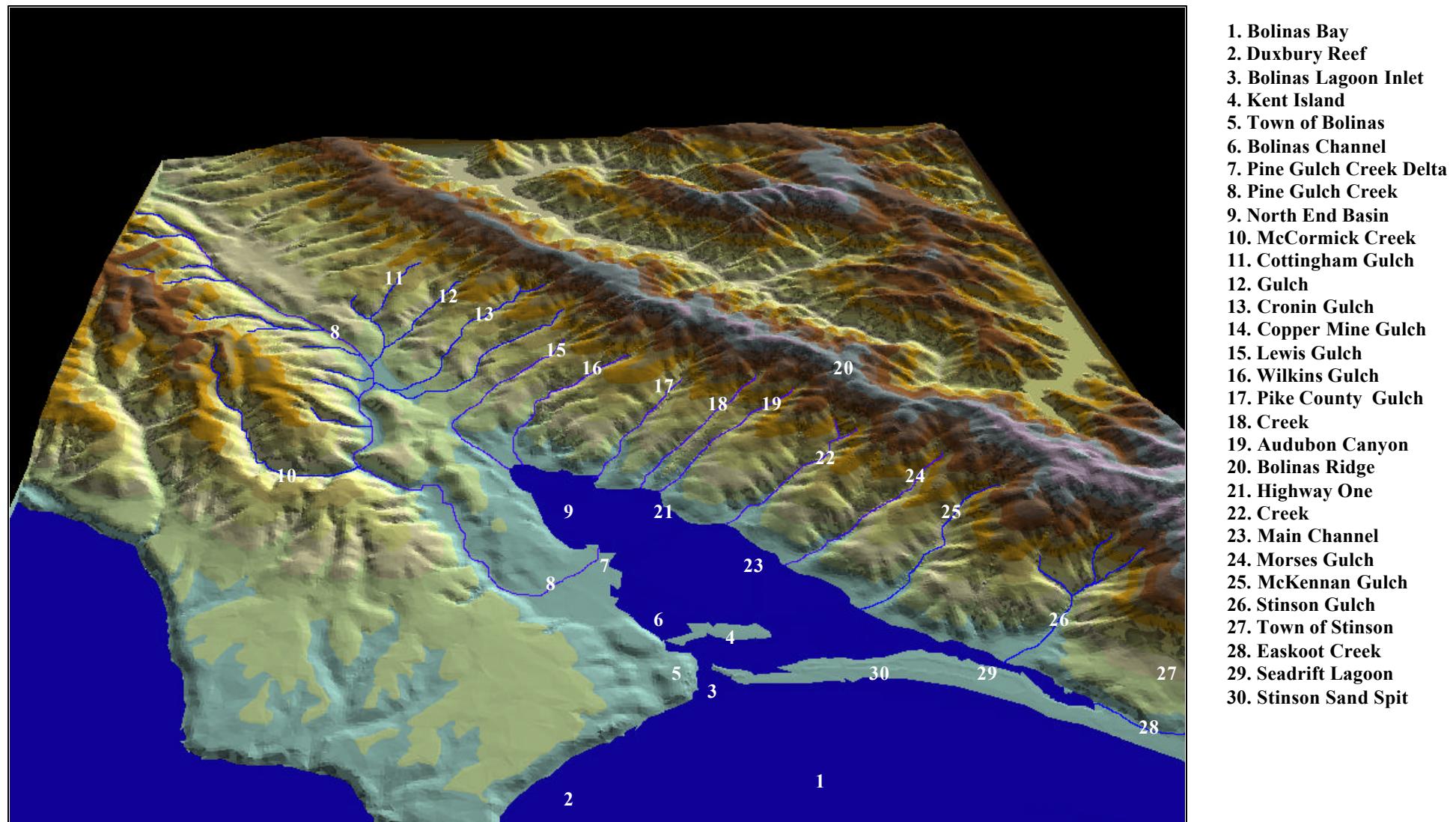


Figure 2 Digital Terrain Model of Bolinas Lagoon

3.2 Historical Sedimentation Rate - Previous Studies

Although there has been general consensus on the source of the above normal sediment entering the lagoon, there are numerous discrepancies among the reports mentioned on the sedimentation rate timeline of the lagoon. Bergquist (1978) attempted to correct the information and methodologies used by other investigators and added information from his own work to create a comprehensive sedimentation rate timeline. However, Bergquist and Wahrhaftig (1993) refuted some of the conclusions reached by Bergquist (1978). The BLMP of 1996 also attempted to summarize the reports and reach a sedimentation rate timeline (shown as Figure 3). As the figure suggests there is still uncertainty in the timeline since it is largely based upon the same information Bergquist used. The Watershed Study of 2001 also summarized many of the previous studies on this topic and although it does not highlight or explain the discrepancies, they are evident in the report.

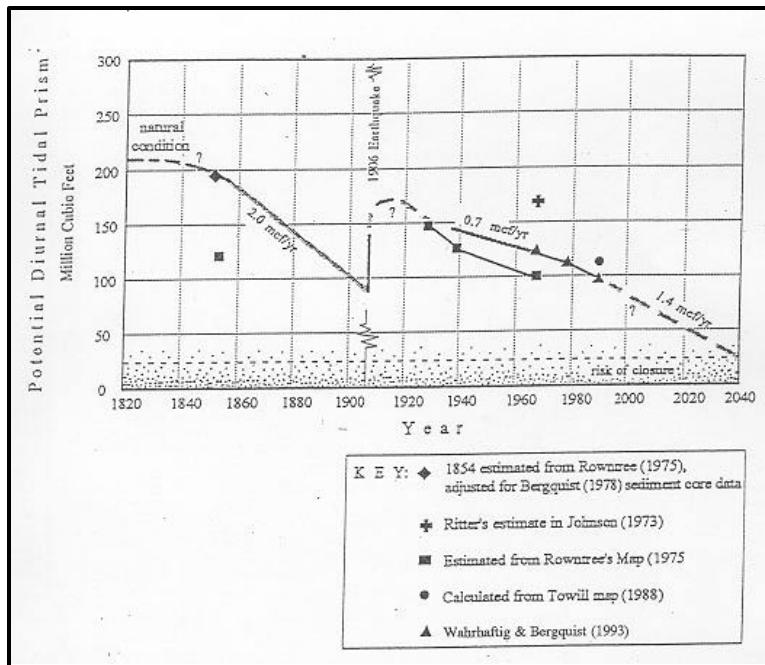


Figure 3 Sedimentation Timeline (BLMP 1996)

3.3 USACE Historical Progression Scenario

According to the BLMP, Bolinas Lagoon is a “self maintaining” system that has not transformed into a meadow due to seismic events along the San Andreas Fault (1996). The seismic activity increases tidal prism by physically dropping the lagoon bottom elevation and causing channel realignment. The USGS determined that significant earthquakes occur along the San Andreas Fault in this region at a fairly regular interval of three hundred to four hundred years (Knudsen *et al.* 1999). This information was used in correlation with the historical transformation of the lagoon to determine the sedimentation rate.

In 1978, Bergquist estimated that the sedimentation rate was 3 mm per year prior to human interaction with ecosystem. This rate was converted to a volume and estimated to be 450,000 ft³ per year, or 16,700 yds³ per year. The average rate from 1850 to 2000 was calculated to be .900 million ft³ to 1.25 million ft³ per year (2 or 3 x 450,000 ft³).

A comparison of the earthquake-based estimation was made to the sedimentation rate time line estimation shown in Figure 3. This was done by summing in million cubic feet the sediment that would have entered the lagoon for each time period and then averaging that over the 150 year time period (Table 1).

Table 1. Sediment Volume Summary and Total

Years	Rate (million ft ³ /year)	Total (million ft ³)
1850 to 1900	2.0	100
1900 to 1970	0.7	49
1970 to 2000	1.4	42
Total Sediment Volume Entered Over 150 Year Period		191
Average Annual Sedimentation Rate Between 1850 and 2000		1.27

A comparison between the two average rates is surprisingly close and provides a level of confidence in the sedimentation rate estimates.

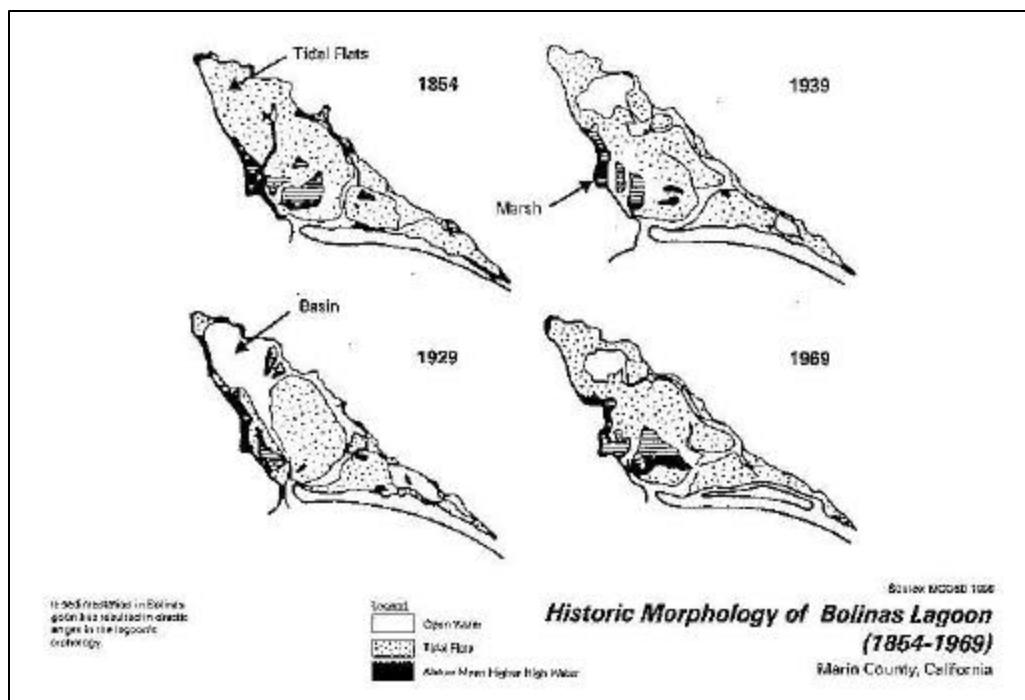


Figure 4 History of the Morphology of Bolinas Lagoon



Figure 5 Aerial Photo of Bolinas Lagoon, March 1998, Low Tide

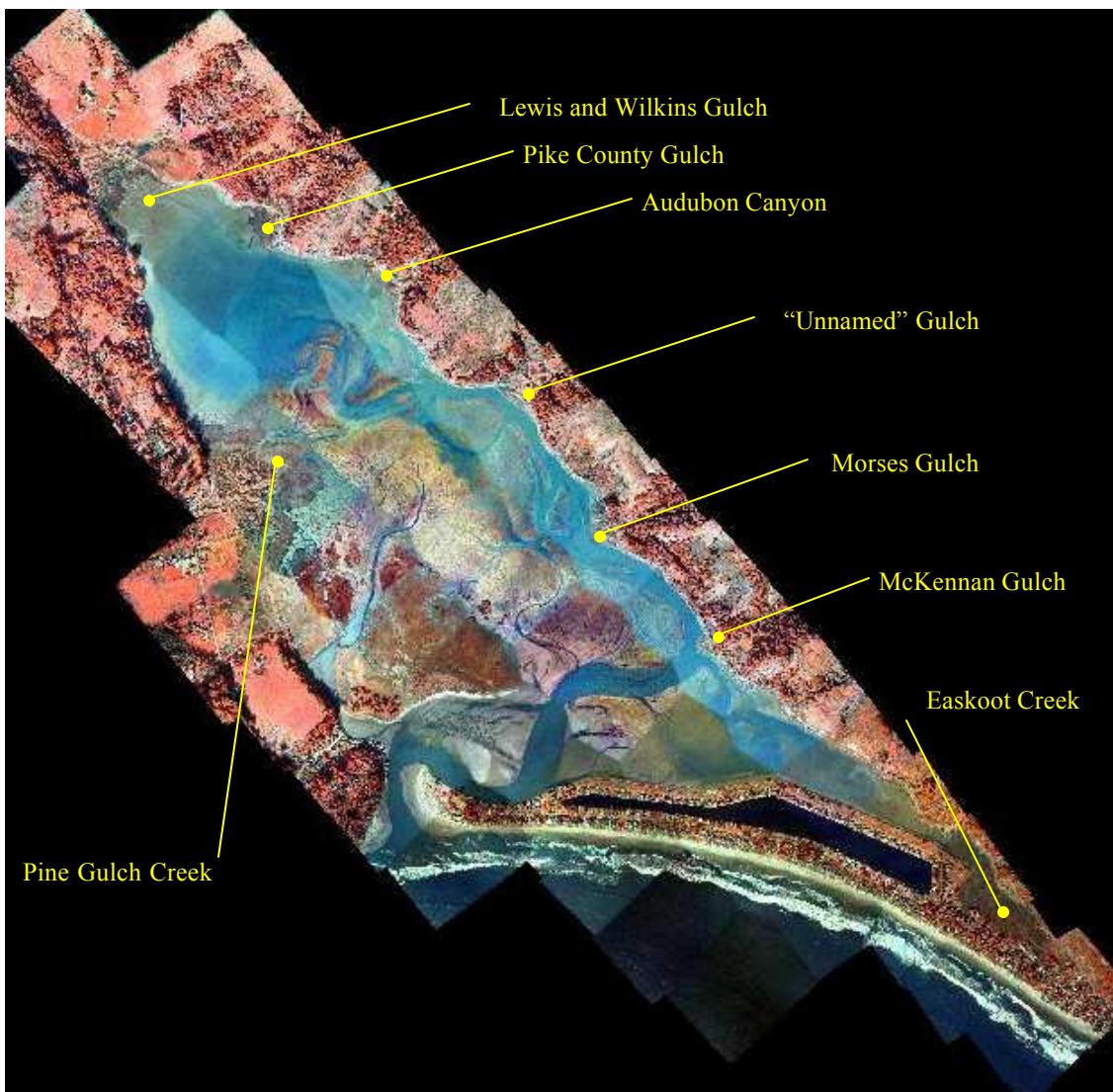


Figure 6 Aerial Infrared Photo of Bolinas Lagoon, 1998

3.4 Sedimentation Rates (1968-1998)

The sedimentation rate calculations were based on the assumption that the change in lagoon volume is directly proportional to the change in sediment volume. Recall from Section 2: Terminology and Definitions, that the spring tide range is 3.15ft to -3.45 ft NGVD and the neap tide range is 2.25 ft to -2.05 ft NGVD. The lagoon volume used in this calculation is the volume of water below the tidal datums of 3.15 and 2.05 ft. The high water elevations of the spring and neap tides were used because they represent extreme values. (During spring tides, high tides are very high and low tides are very low. During neap tides, high tides are not very high and low tides are not very low.)

The lagoon volume was calculated by entering bathymetry data into ArcView, a Geographic Information Systems (GIS) computer program. A 3-D map of the lagoon was created for this data. Lagoon volume was determined from the map. Figure 8 shows

the change in bottom elevation from 1968 to 1998. Figure 10 shows the lagoon volume over time.

The sedimentation rate, or infilling rate, was calculated by finding the change in volume over 10 years between 1968 and 1998 and dividing the result by 10. Figure 7 shows the sedimentation period over time. Figure 7 also shows the approximate normal infilling rate, .45 million ft³ per year. This sedimentation rate was calculated using Berquist's hypothesis that a natural sedimentation rate of the lagoon, excluding human intervention, would be 3 mm per year (1978). Three millimeters was added to each point from the 1968 bathymetry data and the lagoon volumes were recalculated. The lagoon volumes are shown in Figure 11. The infilling rate of .45 million ft³ per year is an average value for the 30 year period of 1968 to 1998. This rate was manually added to the graph in Figure 7 as an asymptotic line.

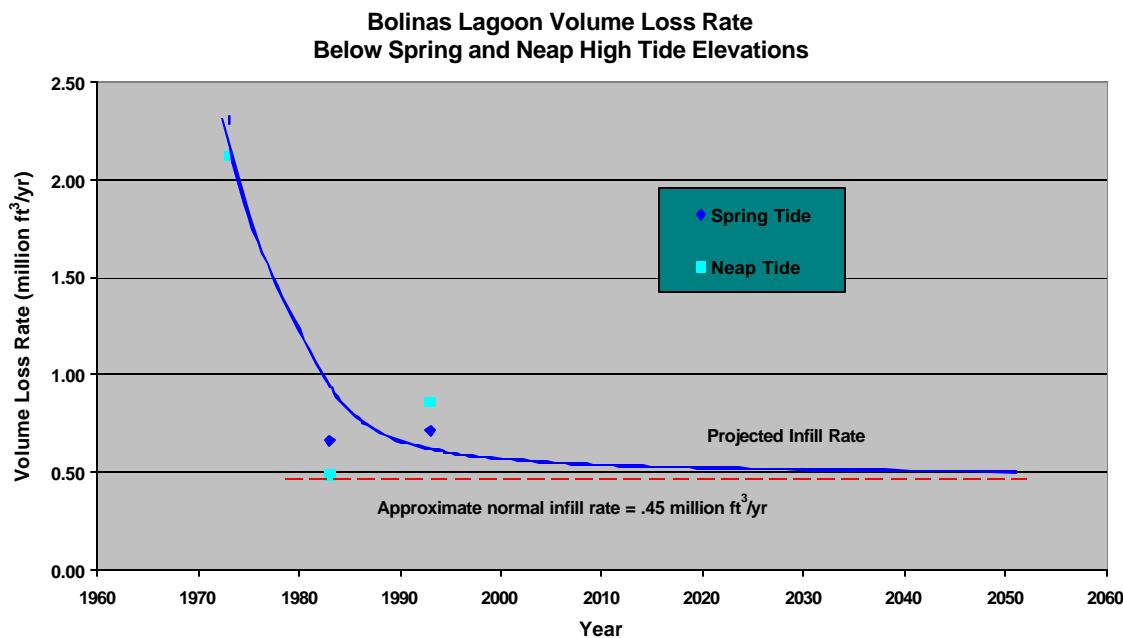


Figure 7 Volume Loss Rate (Sedimentation Rate)

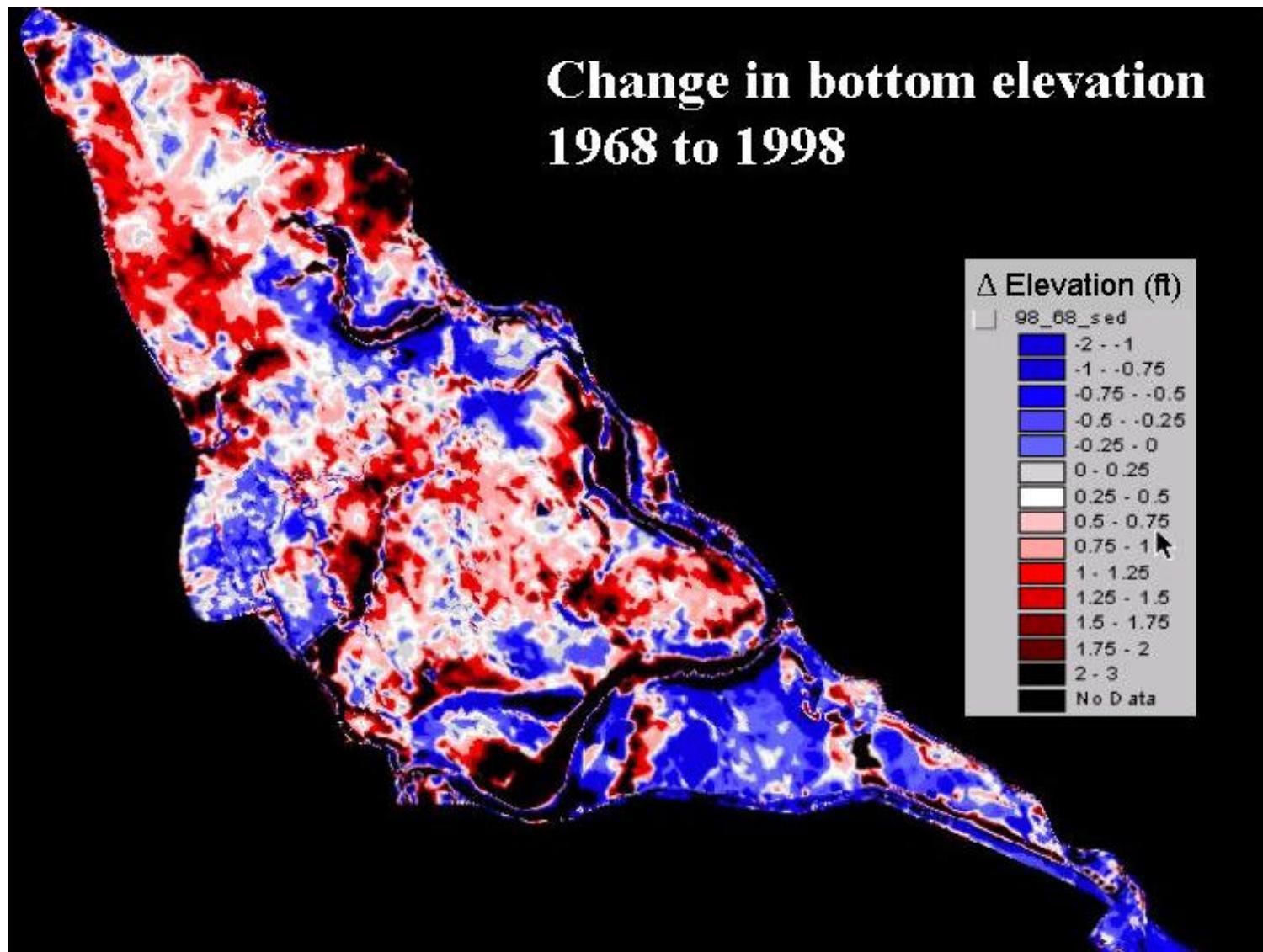


Figure 8 Change in Bottom Elevation, 1968-1998

3.5 Sedimentation Source - Corps Analysis

One aspect of this project was the identification of the source of the sediment that has contributed to the above normal rates associated with the lagoon. Identification was achieved with the use of historical information and a sediment grab sample study.

Historical records show that activities such as logging, clearing, and grazing were common activities in the watershed area. These activities, in addition to the placement of fill material along the edge of the lagoon, were most likely factors in the above normal sedimentation rate. The majority of these activities took place prior to 1970. Logging in the area ceased in 1969. Note that in Figure 7, the sedimentation rate between 1968 and 1978 averaged 2.27 million ft³/year, but decreased steeply to 0.71 million ft³/yr between 1988 and 1998.

The sediment grab sample study was completed in 1998 (PWA 1999). Thirty-five grab samples were obtained in order to determine the following sediment characteristics: mineralogy, angularity, and grain size. It was hypothesized that these sediment characteristics would allow for the identification of the source of the sediment. The results of this work were developed into a grain size map, Figure 9. Figure 9, in addition to Figures 2 and 6, show the locations of the streams entering the watershed.

According to Figure 9, the material in the northern part of the lagoon is very fine sand bordered by a large area of silt to the south. The sediment in the southeast end of the lagoon is composed of gravel at the inlet entrance and fine sand to the north of the inlet. The material in the north part of the lagoon most likely originated from the watershed. If the source of the sediment originated in the ocean (and assuming it was mostly composed of sand and gravel with limited silt), the silt area would most likely be north of the sand area (due to grain size characteristics, sand would drop out first).

Also note the different sediment types found at the entrances of the gulches and creeks to the lagoon in Figure 9. Sediment at the terminus of Pine Gulch Creek is gravel. The sediments at the terminus of the unnamed gulch and Morses Gulch are medium sand and very fine sand. The majority of the gulches, creeks and streams that enter Bolinas Lagoon originate in the Marin County Water District Watershed, located north of the lagoon.

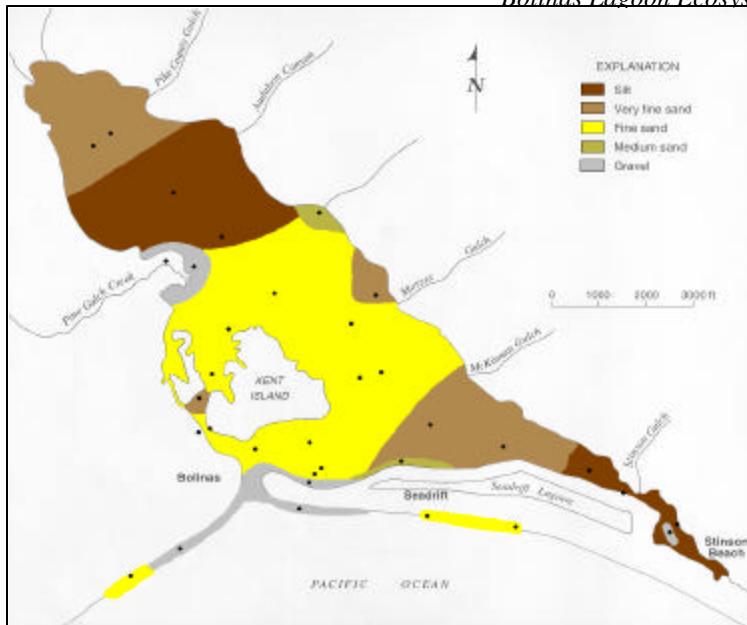


Figure 9 Sediment Distribution Map

3.6 Lagoon Volume

As mentioned in Section 3.4, bathymetric surveys and ArcView software were used to compute lagoon volumes for 1968, 1978, 1988, and 1998. Figure 10 shows the volume within the lagoon below the ocean spring and neap high tide elevations. These water elevations were chosen because of their direct links to the physical processes within the lagoon and habitat measurement. The future volumes (volumes past 1998) in the lagoon were determined using the predicted annual sediment infilling rates from Section 3.4.

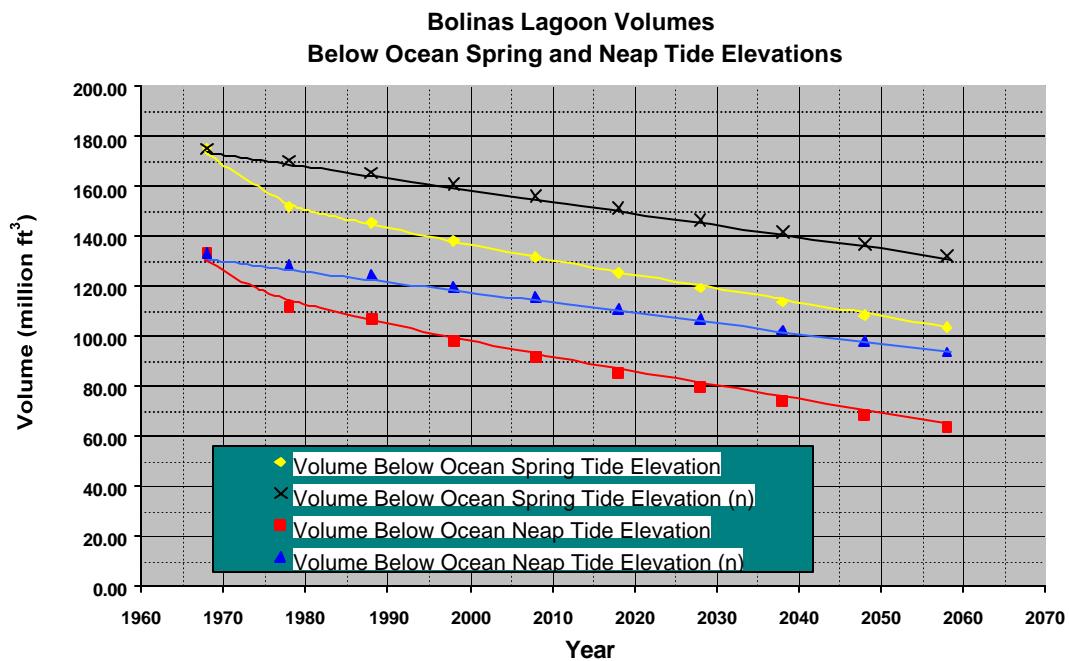


Figure 10 Lagoon Volume Below Ocean Spring and Neap High Tide Elevation

3.7 Water Surface Elevations

In 1968 and 1998 six tide-measuring stations were installed in the lagoon to measure water surface elevations (Ritter 1970, PWA 1999). The 1998 data provided a continuous time series of the water surface elevation for two separate months in spring and fall. The 1968 tide data was acquired from analog script charts by picking several points. These values were used to create a tidal record by interpolating points.

The six tide-measuring stations that were operational in 1998 are listed in the legends in Figures 12, 13, and 14. These figures illustrate phase and amplitude shifts in the tidal curves between stations. The stations closest to the inlet (Bolinas Channel, South Lagoon Channel, and Inlet) show short period oscillations attributed to ocean waves between April 18 and April 20 (Fig. 12), and smaller effects throughout the sampling period. These effects were in the form of swell energy pulsing through the inlet and refracting north and south, where the Inlet, Bolinas Channel, and South Lagoon Channel tide stations are located. This swell energy was also observed by field technicians (PWA 1999).

Meteorological effects include the setup of water in the northern part of the lagoon, attributed primarily to south winds, resulting in hyper-elevated water surface elevations at the North tide station. Figure 12 shows elevated water levels at the North tide station during the high tide on April 16, 17, and 18. Elevated water levels at the North tide station are also evident in Figure 14 on November 6, 7, and 8. The predominant wind during this time period was from the south. Rainfall runoff may also have contributed to the high relative water levels at the North tide station (PWA 1999).

For the spring data set, estimates were made of the lag time from the Inlet Tide Gage for the other five tide gages for both (1) slackwater between flood and ebb tide (maximum water surface elevation and (2) slackwater between ebb and flood tide (minimum water surface elevation). The lag times are listed in Table 2. It was found that the tidal lag times in the far southern, eastern, and northern reaches of the lagoon are quite substantial and correspond qualitatively to the observations made in the field during instrument installation and surveying. The South Lagoon Channel and the Bolinas Channel, the two closest locations to the inlet, exhibit a lag time on the order of just less than an hour (PWA 1999).

Table 2. Estimated Lag Times From the Inlet Tide Gage for Slackwater Between Flood and Ebb Tides and Slackwater Between Ebb and Flood Tides (Minimum Water Surface Elevations)
(Source: PWA 1999).

Tide Recorder Location	South Lagoon Channel	Bolinas Channel	East Channel	South	North
Slackwater Between Flood and Ebb Tide					
Minimum Lag Time (Hours)	0.3492	-0.1509	0.6666	0.6666	2.0530
Maximum Lag Time (Hours)	2.0158	2.1825	2.3333	2.0159	3.9038
Average Lag Time (Hours)	0.9206	0.8103	1.3648	1.1866	3.0939
Standard Deviation (Hours)	0.3668	0.4791	0.3900	0.3768	0.4375
Slackwater Between Ebb and Flood Tide					

Minimum Lag Time (Hours)	0.1667	0.5000	0.6666	0.6667	2.3863
Maximum Lag Time (Hours)	1.6825	1.8491	2.1666	2.6825	4.0000
Average Lag Time (Hours)	0.7608	0.8959	1.2065	1.4663	3.1652
Standard Deviation (Hours)	0.2953	0.3227	0.3753	0.4141	0.3581

Figure 14 shows the water surface elevations for October 14 through November 19, 1998. A pressure transducer was deployed in Bolinas Bay. This data is also plotted in Figure 14, which shows the how much greater the tidal range is in Bolinas Bay as compared to the other tide stations inside the lagoon.

Based on the available data, it was found that although there was considerable variation in water surface elevation across the lagoon at any given time, the tidal range throughout the lagoon was similar. Tidal elevations and ranges in the lagoon were muted compared to the ocean tidal conditions. By comparing the data from within the lagoon to ocean elevation data taken from the Presidio Tide Station (Station # 9414290), reduction factors for ocean elevations to lagoon elevations were determined (see Appendices 1 and 2). This was done for both the spring and neap tide conditions that were defined in Section 2. Figure 11 shows the water surface elevations. The ocean tides were used so that a comparison from year to year could be made.

Figure 15 shows the change in bathymetry in Bolinas Lagoon from 1968 to 1998. These images, created in ArcView, show a decrease in lagoon volume and the reduction in size of some of the lagoon channels.

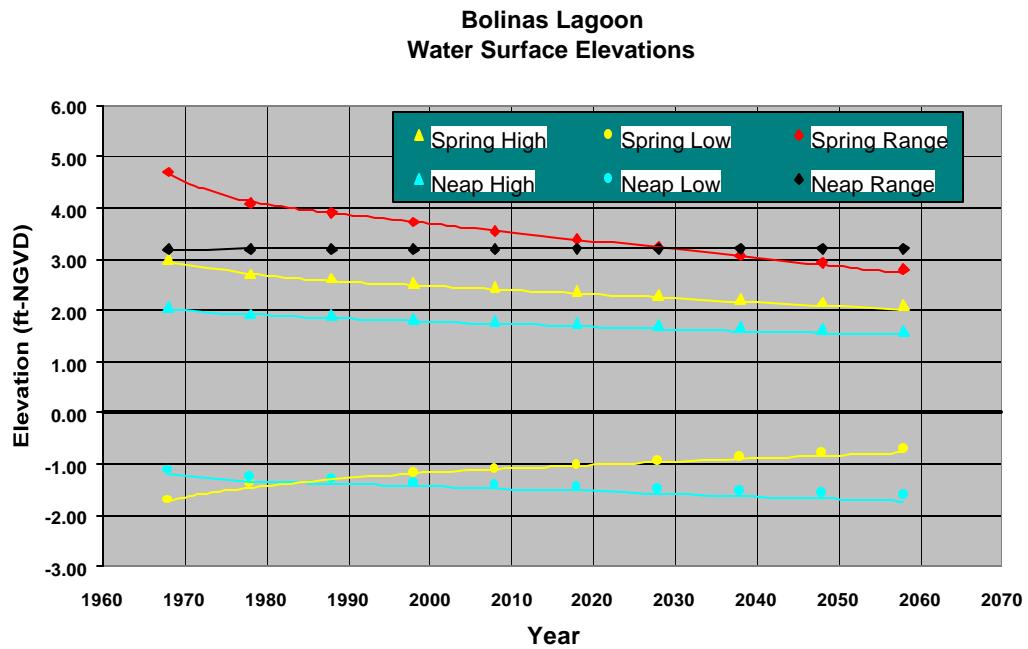


Figure 11 Bolinas Lagoon Water Surface Elevations

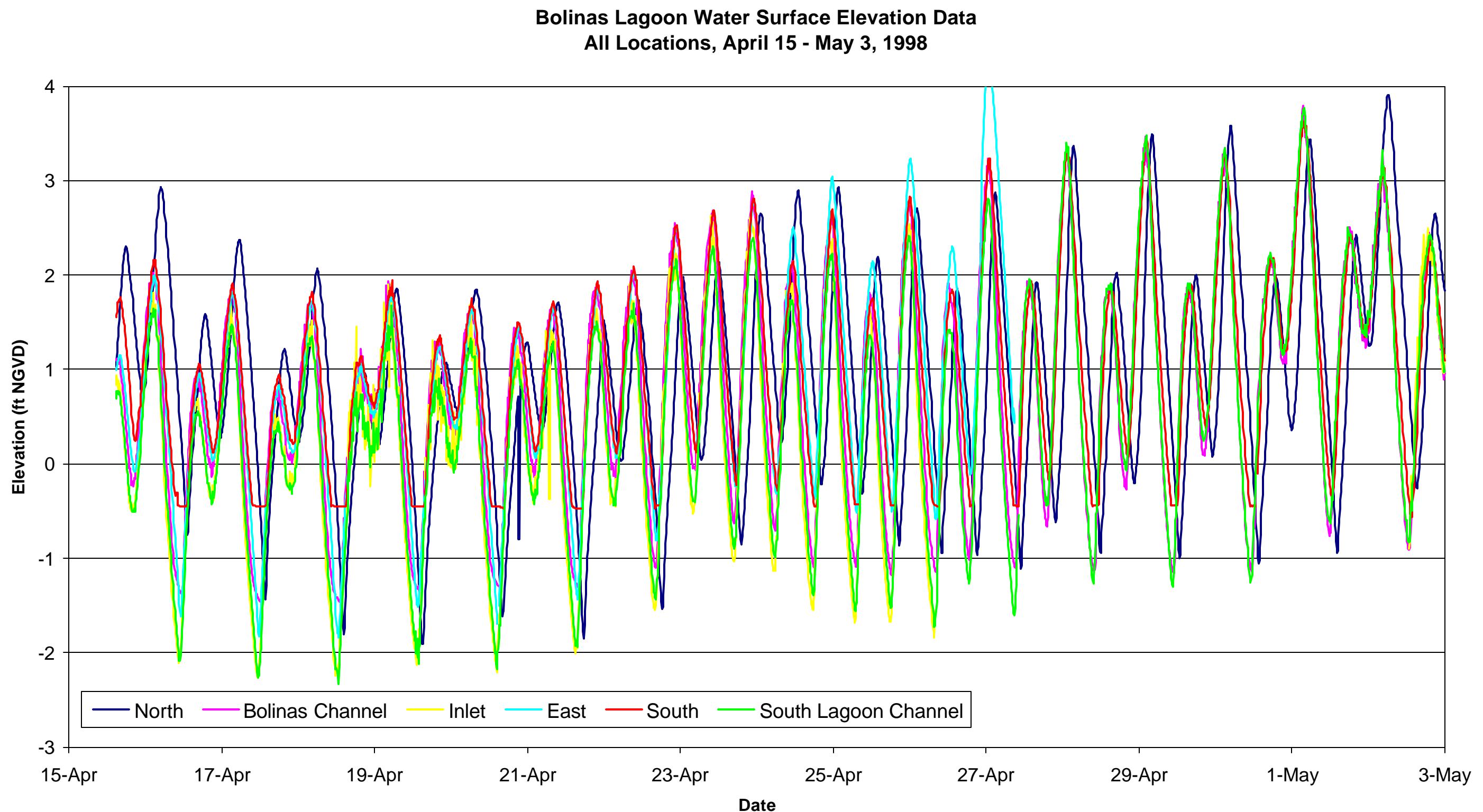


Figure 12 Bolinas Lagoon Water Surface Elevation Data, All Locations, April 15 – May 3, 1998

**Bolinas Lagoon Water Surface Elevation Data
All Locations, May 3 - May 22, 1998**

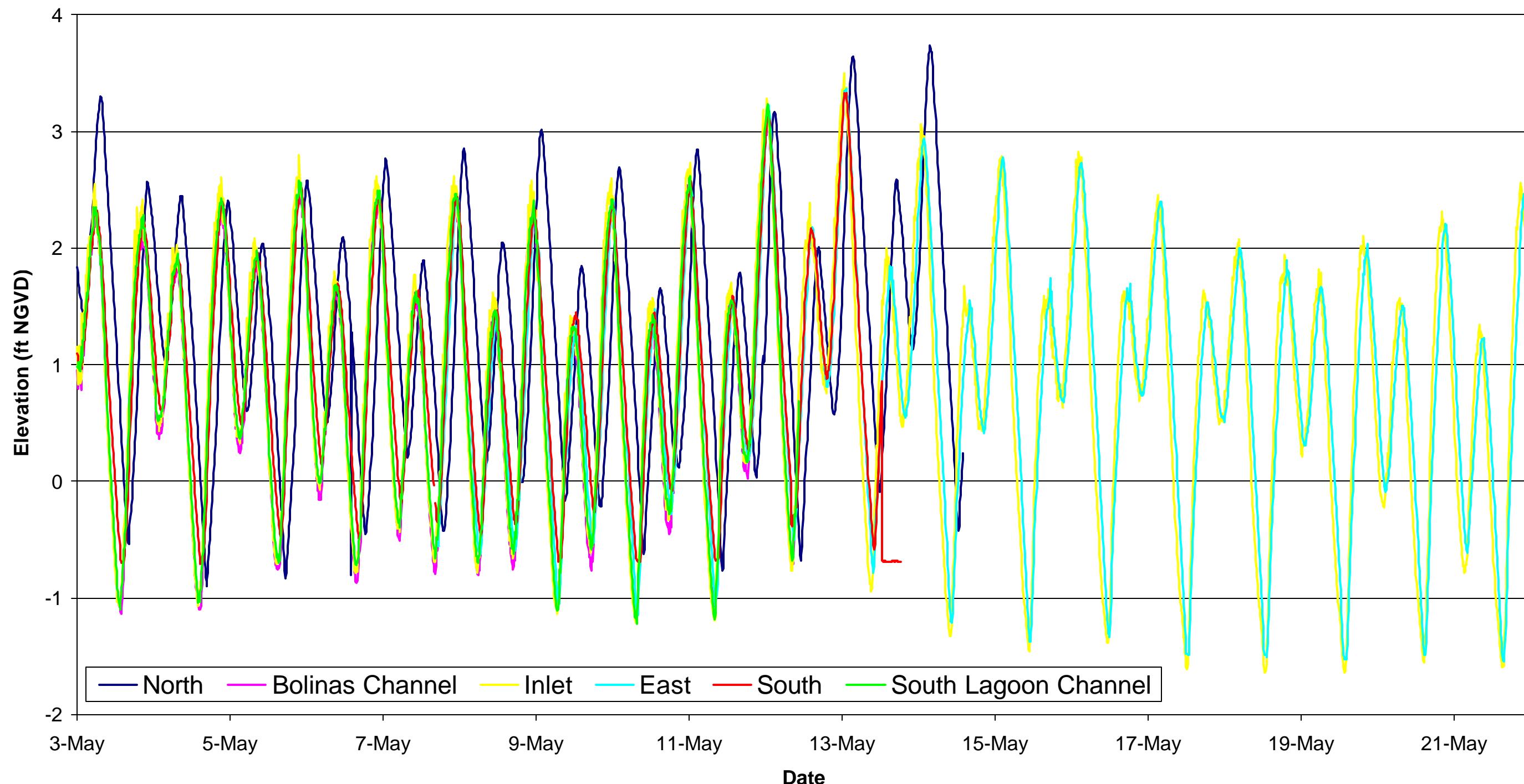


Figure 13 Bolinas Lagoon Water Surface Elevation Data, All Locations, May 3 – May 22, 1998

**Bolinas Lagoon Water Surface Elevation Data
All Locations, October 14 - November 19, 1998**

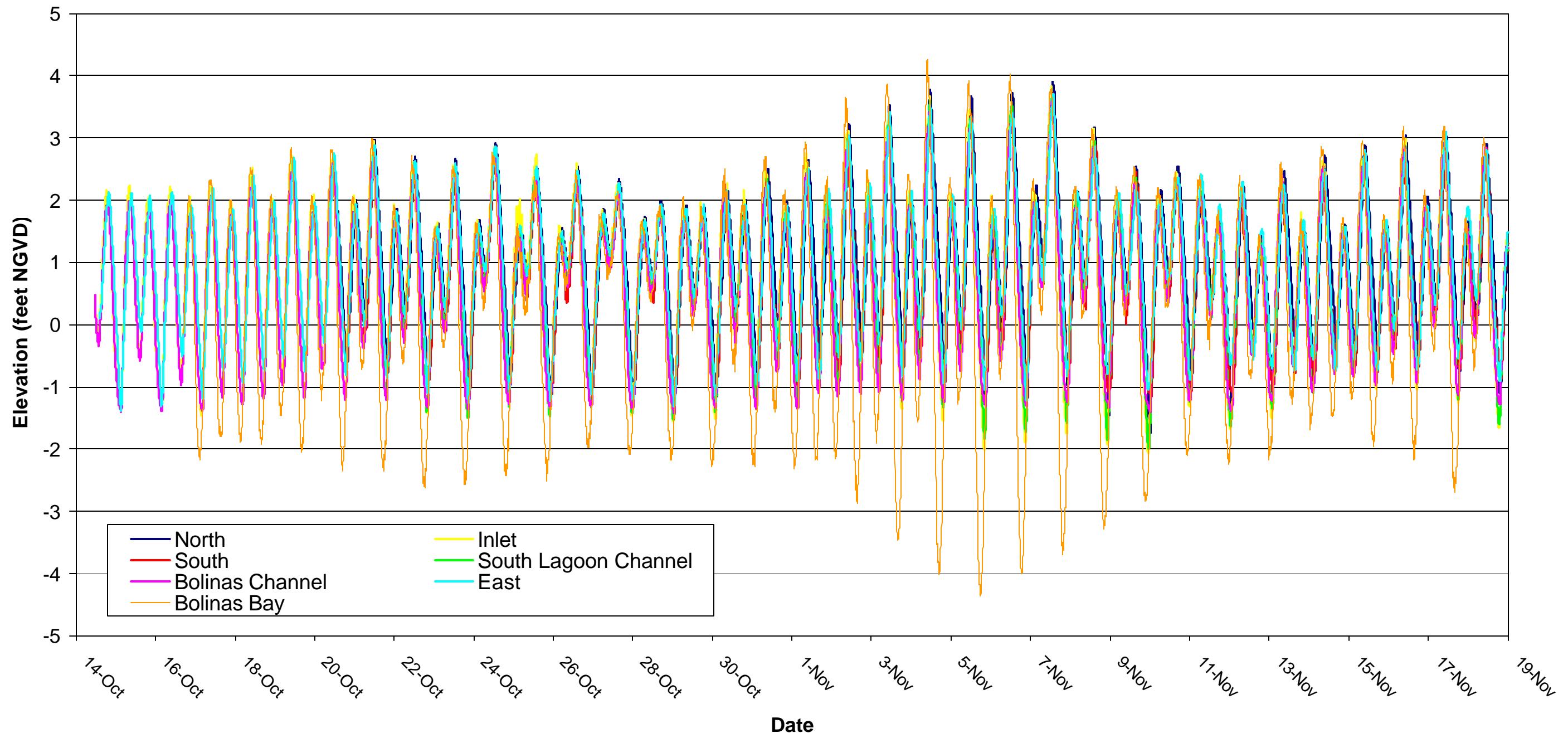


Figure 14 Bolinas Lagoon Water Surface Elevation Data, All Locations (Including Bolinas Bay), October 14 – November 19, 1998

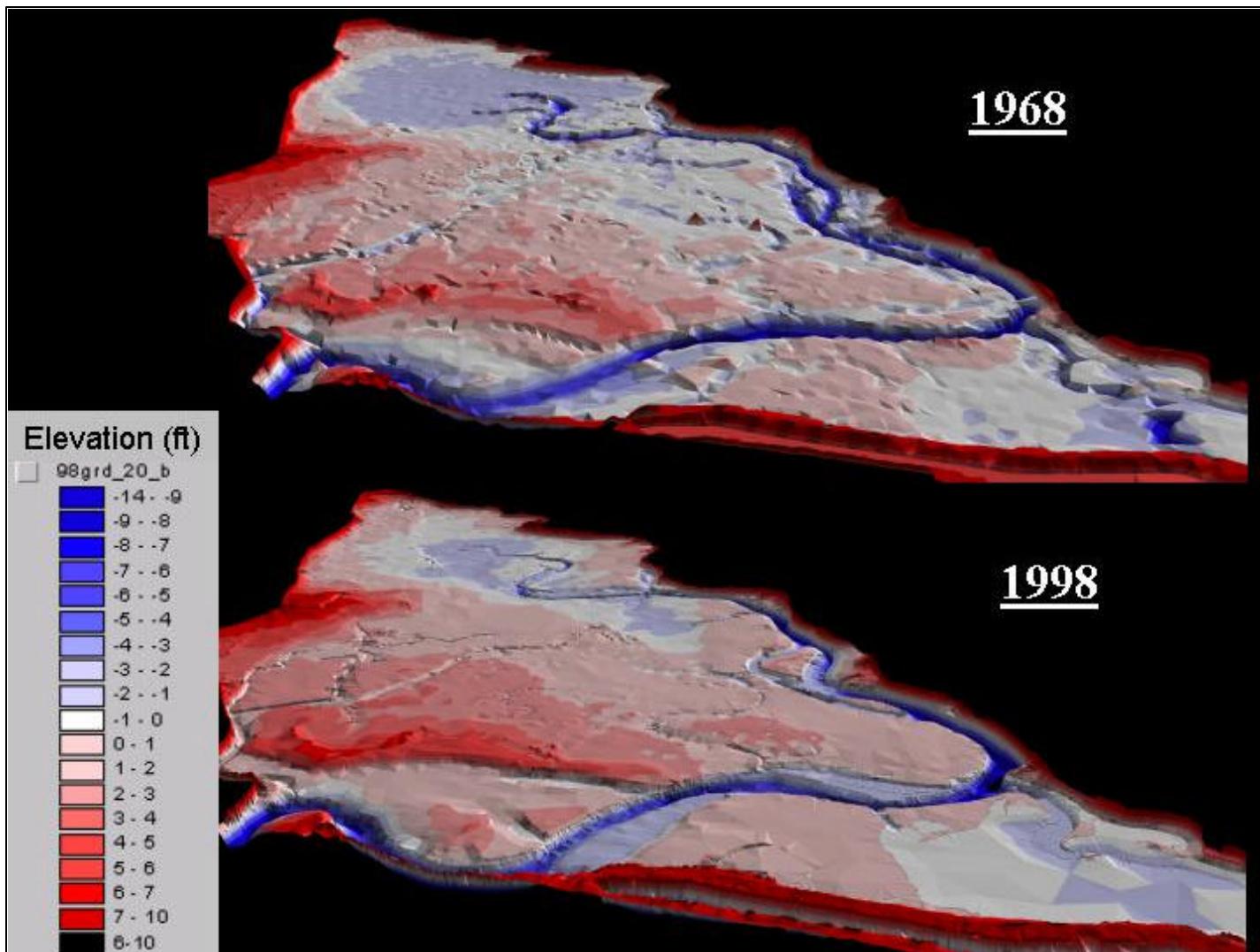


Figure 15 Bolinas Lagoon Bathymetries 3D Digital Terrain Model

3.8 Potential and Effective Tidal Prism (Spring and Neap Tides)

To calculate the potential tidal prism for spring and neap tides, volume associated with a low tide was subtracted from the lagoon volume associated with a high tide corresponding to spring and neap tide events. The difference between the volumes represents the tidal prism. The potential tidal prism values are plotted in Figure 16.

The effective tidal prism for 1968 and 1998 was calculated by multiplying the potential tidal prism volume by a ratio. Ratios were calculated for 1968 and 1998. This ratio was the average of four ratios. It was computed by dividing effective tidal prism by potential tidal prism. The effective tidal prism values used in the ratio calculation were computed by finding the difference between the volume of the lagoon under the maximum and minimum water surface elevations associated with tidal events during the months of August and September in 1968 and 1998. The calculation of the potential tidal prism used in the ratio computation is described in the next paragraph.

Recall from Section 2 that the definition of potential tidal prism is the volume of water that would enter and exit the lagoon if the elevations within the lagoon matched the ocean elevations. A uniform water surface elevation was assumed, and the potential tidal prism values were calculated as the difference in water volume between high and low tides.

In a similar manner, the effective/potential tidal prism ratio was determined for 1978. For 1978, the effective tidal prism ratio was calculated in three steps. The difference between the 1968 and 1998 ratios was divided by the difference in lagoon volumes for those years. This value was multiplied by the difference between the lagoon volume for 1968 and the volume in 1978. Lastly, the resulting value was subtracted from the 1968 ratio. The ratios for 1988 and 2008 through 2058 were calculated in a similar manner (see Section 3.8.1).

As mentioned above, the effective tidal prism was calculated by multiplying the lagoon volume by these ratios. The effective tidal prisms are shown in Figure 16.

The potential tidal prism changed by 21.4% between 1968 and 1998. The effective tidal prism changed by 38.9% during the same time period. In Figure 16, the potential tidal prism is greater than the effective tidal prism for both spring and neap tide conditions. Both potential and effective tidal prism for spring and neap tide conditions decrease over time.

3.8.1 Predicted Tidal Prism

In order to calculate tidal prism values for 2008 to 2058, an estimation of future lagoon volumes and sedimentation rates was required. Sedimentation rates were computed for 10-year periods from 1998 to 2058 for the following elevation levels: -3.45, -2.05, 2.25, and 3.15 ft NGVD. For 2008, the sedimentation rate for 1998 to 2008 was multiplied by 10 and subtracted from the 1998 lagoon volume corresponding to a 3.15-foot water

surface elevation (tidal datum). The lagoon volumes for 2018 through 2058 were calculated in a similar manner for all four elevation levels.

For 1998, the potential tidal prism for the spring tidal condition is the difference between the 3.15 and -3.45-foot elevations, which is the spring tidal range. The potential tidal prism for the neap tide is the difference between the 2.25 and -2.05-foot elevations. For 2008, the predicted tidal prism associated with a spring tide elevation is the 1998 tidal prism value multiplied by a tidal prism ratio of .955. The tidal prism values associated with neap tide conditions were computed in a similar manner with a ratio of .892.

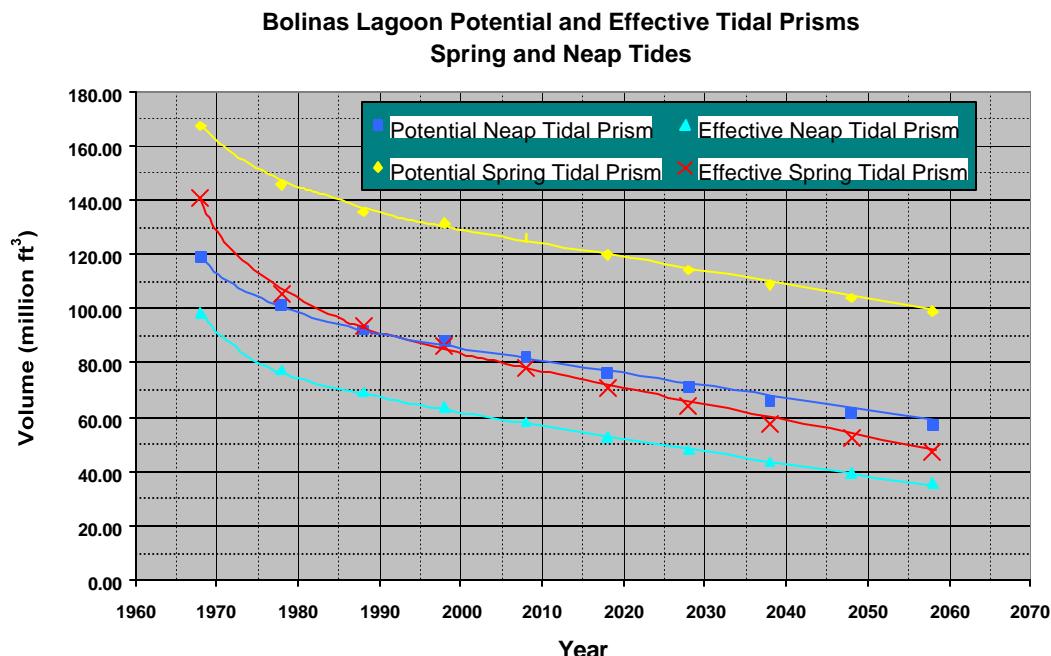


Figure 16 Bolinas Lagoon Potential and Effective Tidal Prism

3.9 Inlet Characteristics

Inlet channel characteristics depend on a balance between (1) tidal prism which transports sand through the mouth of the inlet; (2) longshore sediment transport and waves that transport sand across the inlet mouth; and (3) fresh water discharges from the lagoon that scour the inlet. Inlet opening conditions strongly influence depth, duration, and frequency of inundation throughout the lagoon, and the extent and distribution of habitats (Kamman 2001). For this study, the inlet cross sectional area, stability, and closure were evaluated.

3.9.1 Cross-Sectional Area

The inlet cross sectional area was calculated using a relationship between minimum cross-sectional area below mean tide level and the tidal prism at spring tide (O'Brien 1969, Jarrett 1976):

$$A_c = 1.19 \times 10^{-4} (P^{0.91}) \quad (1)$$

A_c = Inlet Cross Sectional Area (ft^2)

P = Spring Tidal Prism (ft^3)

Using this equation, Bolinas' inlet size ranges from 1130 ft^2 in the spring to 1050 ft^2 in the fall. Cross-sectional profiles are plotted in Figures 17-19. Survey data was used to create these profiles.

Figure 17 shows how the fall profile of the inlet has reduced in size from 1967 to 1998. Figure 19 compares the spring profile of the inlet from 1957 to 1998. The 1998 spring profile shows that the inlet has become shallower. Figure 18 compares the spring and fall inlet cross sectional profiles. This figure shows that the inlet varies in depth and width throughout the year.

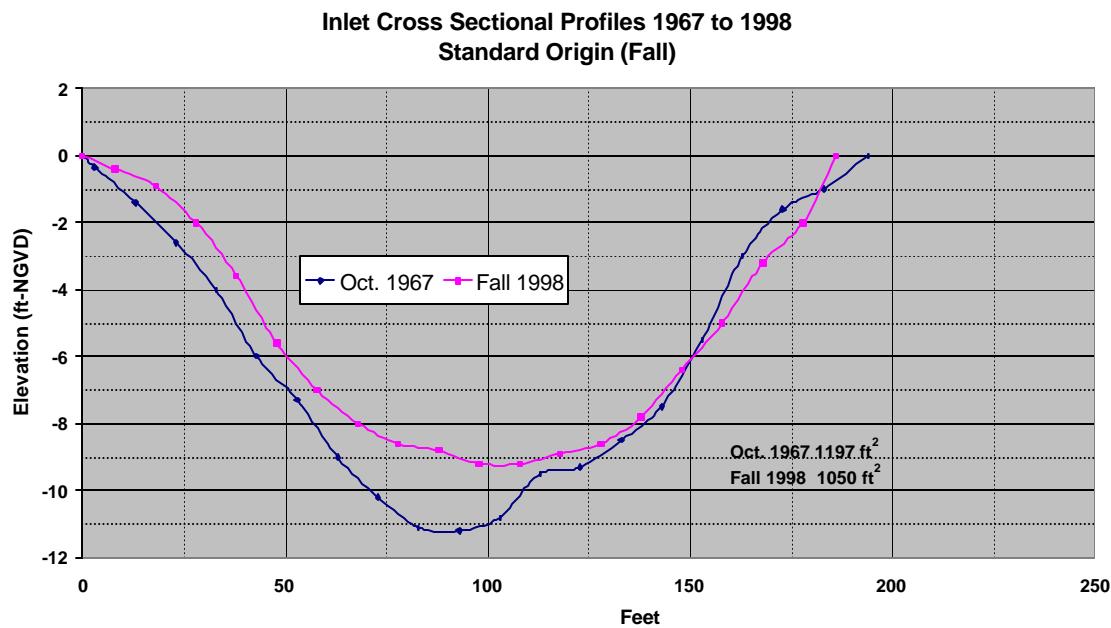


Figure 17 Inlet Cross Section Profiles (1967, 1998)

Spring and Fall 1998 Inlet Cross Sectional Profiles

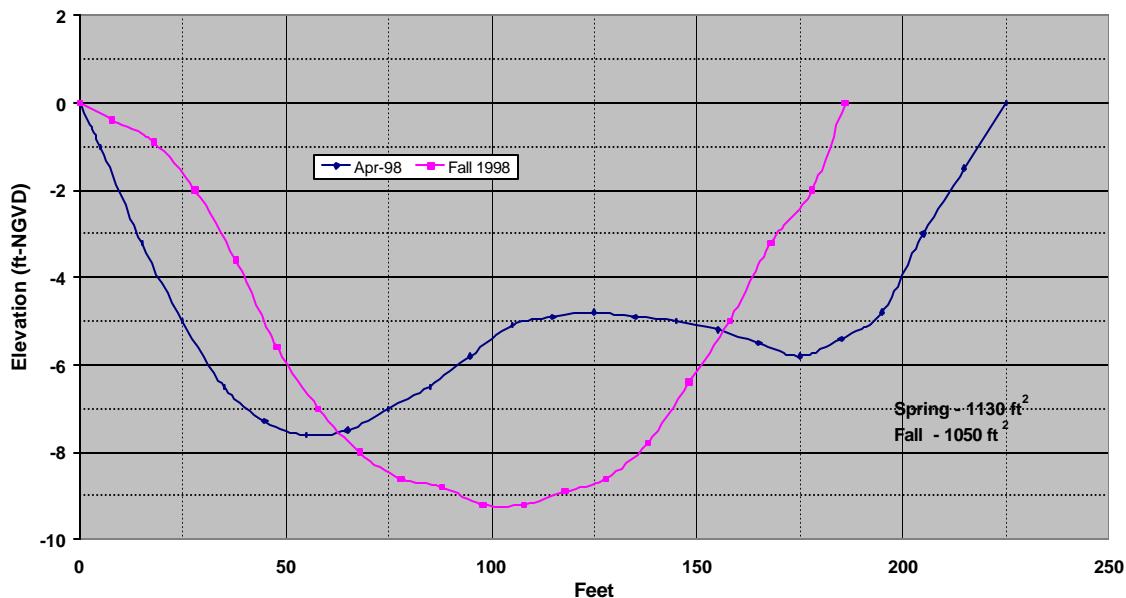


Figure 18 Spring and Fall 1998 Inlet Cross Section Profiles

Inlet Cross Sectional Profiles 1957 to 1998 - Standard Origin (Spring)

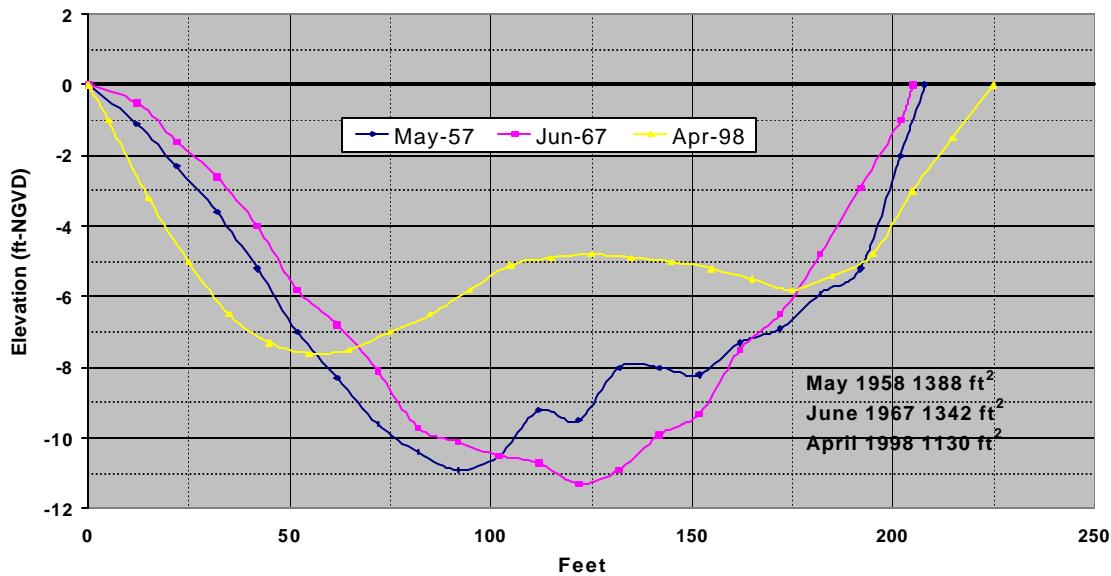


Figure 19 Inlet Cross Section Profiles (1957, 1967, 1998)

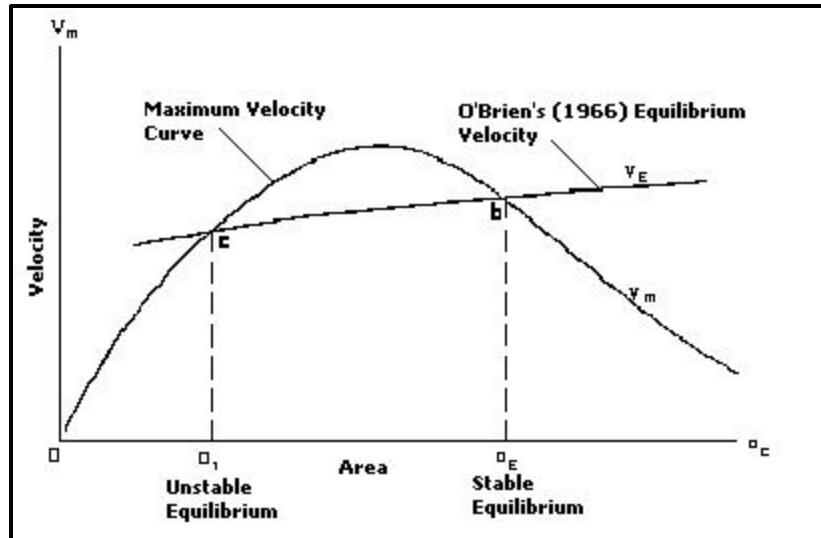
3.9.2 Inlet Stability

Seabergh and Kraus developed a computer program to determine the stability of a lagoon/inlet system (1997). The underlying theory was based upon work presented by

Escoffier (1940, 1977). In this work, O'Brien's equilibrium velocity data (1966) and the maximum inlet velocity were plotted versus inlet cross-sectional area (Figure 20).

The first curve is a plot of velocity versus an inlet's cross-sectional flow area, A_c . As area approaches 0, velocity approaches 0 due to increasing frictional forces. As channel area increases, frictional forces are reduced. On the far right side of the curve, velocities decrease once the tidal prism has reached a maximum. Any area increase results in a decrease of flow velocity through the inlet. This curve can be constructed by calculating the velocity, V_m , by varying the channel area, A_c . V_m can be determined by an analytical or numerical model. The other curve V_E is a stability criterion curve. The curves could intersect at two locations, one location, or there can be no intersection. Point b is a stable root. If channel area increases (moves to the right of b), velocity will fall and more sediment can fill in the channel to bring it back to "equilibrium." If area decreases, velocity will increase scour back to the equilibrium point. Point c is an unstable root, where if area decreases, velocities decrease until the inlet closes. If the stability curve falls tangent to the stability criterion curve, the inlet will close. If inlet area is to the right of the unstable equilibrium point, and an event occurs that provides a large sediment input to the inlet region, the inlet area could shift to the left of that point and the inlet would close (*SPM: Hydrodynamics of Tidal Inlets* 2001).

The method outlined in the preceding paragraph was applied to Bolinas Lagoon. A cross-sectional area of 1050ft^2 was used. This area falls to the left of the stability curve, or maximum velocity curve. This suggests that the inlet is in a state of unstable equilibrium (see Fig. 21).



**Figure 20 Maximum Velocity vs.
Inlet Cross-Sectional Area (Seabergh and Kraus 1997)**

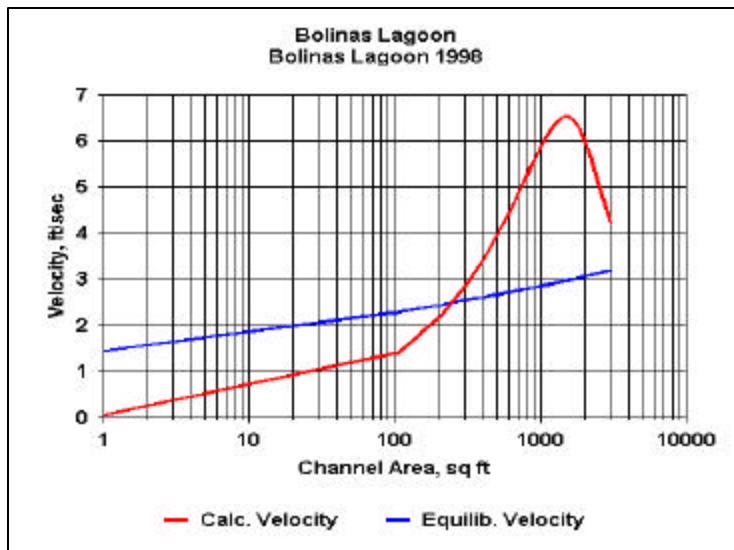


Figure 21 Position of Bolinas Lagoon's Inlet on Maximum Velocity Curve

3.10 Inlet Closure

A second method used to describe inlet stability is the closure index, which estimates the likelihood of inlet closure. Inlet closure is possible either under the conditions defined in the previous section or when there is a coincidence of high wave energy and weak ebb velocity (Williams and Cuffe, 1994). Weak ebb velocities occur during neap tides; when the tidal prism is small; and when stream flow (which adds to ebb velocities) is low. (Although the tidal prism has reduced over time, Bolinas Lagoon has never experienced a closure.)

Prediction of closure can be determined using wave power of extreme events to calculate closure criterion developed by O'Brien. O'Brien's theory is based upon finding the ratio (closure index - C) of the two most substantial opposing forces affecting an inlet's stability, wave power and tidal or ebb flow power through the inlet (Equation 2).

$$C = \Phi_W/\Phi_T \quad (2)$$

C = closure index

Φ_W = wave power

Φ_T = tidal power

Tidal power is calculated with Equation 3:

$$\Phi_T = (\gamma h_r/b)(P/T_t + Q) \quad (3)$$

Q = fresh water input (ft^3/s)

h_r = potential tidal range (ft)

b = width of entrance channel

T_t = tidal period (s)

P = potential neap tidal prism (ft^3)

Wave power was determined from a wave analysis study conducted during the fall of 1998 for a duration of a little over a month (PWA, 1999). The goal of the study was to estimate wave power incident to Bolinas Lagoon. A wave gage was deployed on the floor of Bolinas Bay approximately one mile south of the inlet channel in order to relate open ocean swell to swell conditions incident to the entrance of Bolinas Lagoon. The gage provided the following data: significant wave height, peak period, and peak direction. This data was compared to output from a wave refraction model applied from deep water to Bolinas Bay. The deep water wave data used in the model was taken from records for the Point Reyes and Monterey Bay Buoys, the two closest directional gages. The Monterey Buoy has been collecting data since 1987, and it is the longest continuous deep water directional wave data set on the west coast. PWA found that the model validation study yielded sufficiently accurate model results to warrant the use of the model transformation coefficients, and the deep water directional data from NOAA Buoy 46042, to study the potential for wave induced closure of Bolinas.

The wave power used in Table 3 is an average value. PWA found that the wave power at the inlet was significantly less than the deep water wave power (1992). Wave power is also greater in winter months (Jan. – March) and decreases during spring and summer months (April – Aug., Sept. – Dec.).

The inlet closure method developed by O'Brien is based on his work on entrance channels of Pacific Coast lagoons. It is an empirical closure relationship. Prediction of closure for an inlet is usually compared to closure indices of other inlets. The prediction is based upon physical similarities between inlets. In this study, Bolinas Lagoon was compared to the Russian River Estuary, the mouth of which is fully exposed. The Russian River experienced closure at values of about 12 (Williams and Cuffe, 1994).

The closure indices are listed in Table 3 for 1968 through 2058. Fresh water input was not considered in this calculation. The closure indices in Table 3 range from 7 to 16. Inlet closure for Bolinas Lagoon could begin as soon as 2018.

Table 3. Closure Index (Zero Fresh Water Flow)

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	82.10	250	4.3	0	4,017	45,000	11.2
2018	76.52	250	4.3	0	3,744	45,000	12.0
2028	71.23	250	4.3	0	3,485	45,000	12.9
2038	66.21	250	4.3	0	3,239	45,000	13.9
2048	61.47	250	4.3	0	3,007	45,000	15.0
2058	57.01	250	4.3	0	2,789	45,000	16.1

In order to gauge the accuracy of the modified O'Brien Closure Index Equation, a sensitivity analysis was performed. A fresh water flow rate was incorporated into the closure index calculation, and the size of the inlet width was altered. Using a discharge

rate of 700 ft³/sec for Pine Gulch Creek, which is characteristic of a 1969 winter storm event, the closure index is reduced to 12.7 in the year 2058. The discharge rate was obtained from the 2001 Watershed Study and reflects a three-year flow rate period.

If the inlet width is changed to 225 feet instead of 250 ft, the closure index in the year 2058 was reduced to 14.5. When the discharge rate of 700 ft³/sec is combined with an inlet width of 225 feet the closure index in the year 2058 is reduced to 11.4.

4 Habitat Definitions

In order to quantify habitats, the lagoon was divided into three habitat types: upland, intertidal, and subtidal.

- Upland - The area that remains above the water line at high tide during a typical spring tide (ocean high tide of 3.15 feet NGVD). The MHHW elevation for the ocean adjacent to Bolinas Lagoon is 2.88 feet NGVD. Upland habitat is that which falls between 7 ft to 2.54 ft NGVD.
- Intertidal - The area that experiences wetting and drying during a one-month period with typical spring and neap tides. Intertidal habitat is that which falls between 2.54 ft to –1.36 ft.
- Subtidal - The area that remains submerged during a typical spring or neap tide (ocean low tide elevation of –3.45 ft NGVD or –2.05 ft NGVD, respectively). The tide that produced the lower elevation within the lagoon was used. Subtidal habitat is that which falls below –1.36 ft.

4.1 Habitat Quantification

For 1968 through 1998, surface area and volumes for the habitats were calculated in ArcView using water level (tide) data and bathymetric surveys. The habitat acreage and volume is listed in Tables 3.

The lagoon volumes for 1968 through 1998 are also shown in Table 4. The upland habitat area was calculated by subtracting the water level at 2.82 ft NGVD from the water level at 7 ft. The intertidal habitat area and volume was calculated by subtracting the area and volume associated with an elevation of –1.49 ft from 2.82 ft. The subtidal area and volume are the area and volume associated with an elevation of –1.49 ft.

According to Table 4, the lagoon volume levels have decreased since 1968, and upland acreage has increased. Intertidal acreage has decreased over time. The subtidal acreage decreases till 1998. Subtidal volume decreases from 1968 to 1978, increases in 1988, and decreases in 1998. This trend is unusual in that the subtidal acreage and volume should decrease over time. An error may have been made in the survey techniques, resulting in erroneous bathymetric data. This error is also evident in Figures 22 and 23, which show the areas and volumes of the different habitats.

Table 4. Historical Habitat Levels

Year	Lagoon Volume (3.15' NGVD) yds ³	Upland acres	Upland yds ³	Intertidal acres	Intertidal yds ³	Subtidal acres	Subtidal yds ³
1968	6,489,855	155.82	7,634,688	876.12	5,580,284	213.38	641,298
1978	5,635,908	197.29	7,943,862	867.50	4,363,639	157.06	533,966
1988	5,390,737	243.43	7,894,691	844.65	3,868,717	127.25	690,093
1998	5,126,588	238.10	8,243,436	848.53	3,584,714	146.39	523,318

In order to calculate future habitat levels, the future lagoon volumes were required. The calculation of the future lagoon volumes used sedimentation rates (mcf/yr). The 2008 lagoon volume was calculated by subtracting sediment deposition for 1998 through 2008 from the 1998 water levels. For the 2018 volume, sediment deposition for 2008-2018 was subtracted from water elevations. Subsequent volumes were calculated in a similar manner. The lagoon volumes, measured in yd³, are listed in Table 5. The *without project* habitat levels were calculated in the same manner as the historical habitat levels. According to Table 5, the lagoon volume decreases over time. The upland habitat acreage increases, while both the intertidal and subtidal acreages decrease. Figures 22 and 23 show future trends in habitat surface area and volume under *without project* conditions.

Table 5. Without Project Habitat Projection

Year	Lagoon Volume yds ³	Upland acres	Upland yds ³	Intertidal acres	Intertidal yds ³	Subtidal acres	Subtidal yds ³
2008	4,883,508	252.77	8,351,980	843.61	3,228,889	134.45	502,281
2018	4,652,007	266.74	8,455,354	838.92	2,890,014	123.07	482,246
2038	4,223,741	292.59	8,646,590	830.25	2,263,112	102.03	445,183
2058	3,841,791	315.64	8,817,144	822.52	1,704,008	83.26	412,128

In the year 2058, predictions indicate that the lagoon will contain 8.8 million yds³ of upland habitat (316 acres), 1.7 million yds³ of intertidal habitat (823 acres), and 412,128 yds³ (83 acres) of subtidal habitat. Compared to the 1998 habitat levels, this represents a loss of 1.9 million yds³ of intertidal habitat and 111,190 yds³ of subtidal habitat. There is gain of 1.2 million yds³ of upland habitat.

Figure 24 shows the lagoon volume versus elevation for 1968 through 1998. From this figure, the greatest volume in the lagoon is associated with upland habitat. The lesser volume is associated with subtidal habitat. This figure also shows the error noted in the previous section: subtidal habitat acreage is greater in 1988 than the other three years.

Figure 25 shows the surface area versus elevation for 1968 through 1998. In this figure, the 1998 data shows an increase in surface area at the elevation associated with upland habitat.

Figures 26 through 30 are aerial photographs of Bolinas Lagoon taken in 1942 up to 1997. The conversion of portions of the lagoon to upland habitat is evident in there area around Pine Gulch Creek. The development of Kent Island is also noticeable. (Kent Island presently has vegetation on it.) The geometry of the spit at the very end of the Seadrift community has also changed over time.

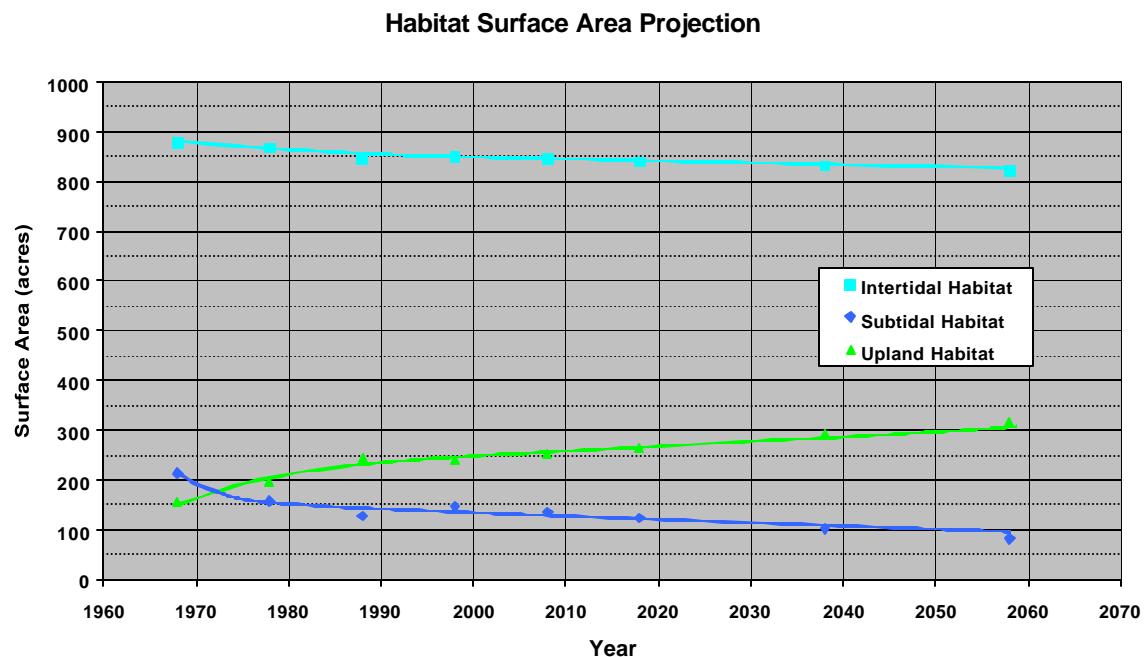


Figure 22 Habitat Surface Area

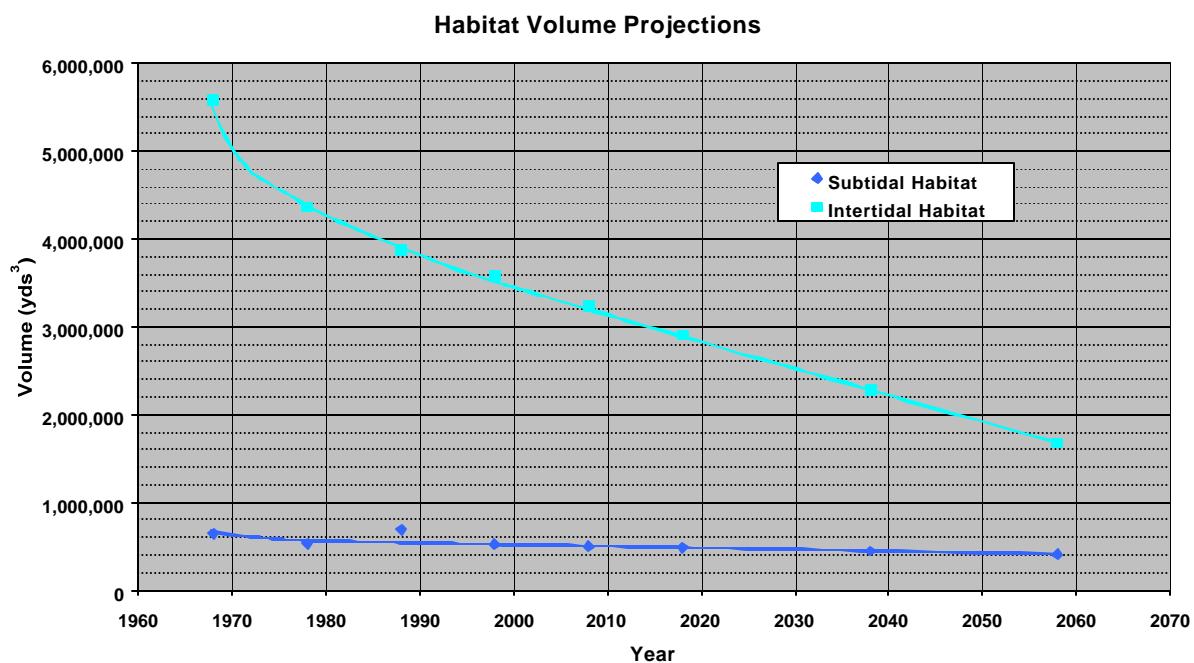


Figure 23 Habitat Volume

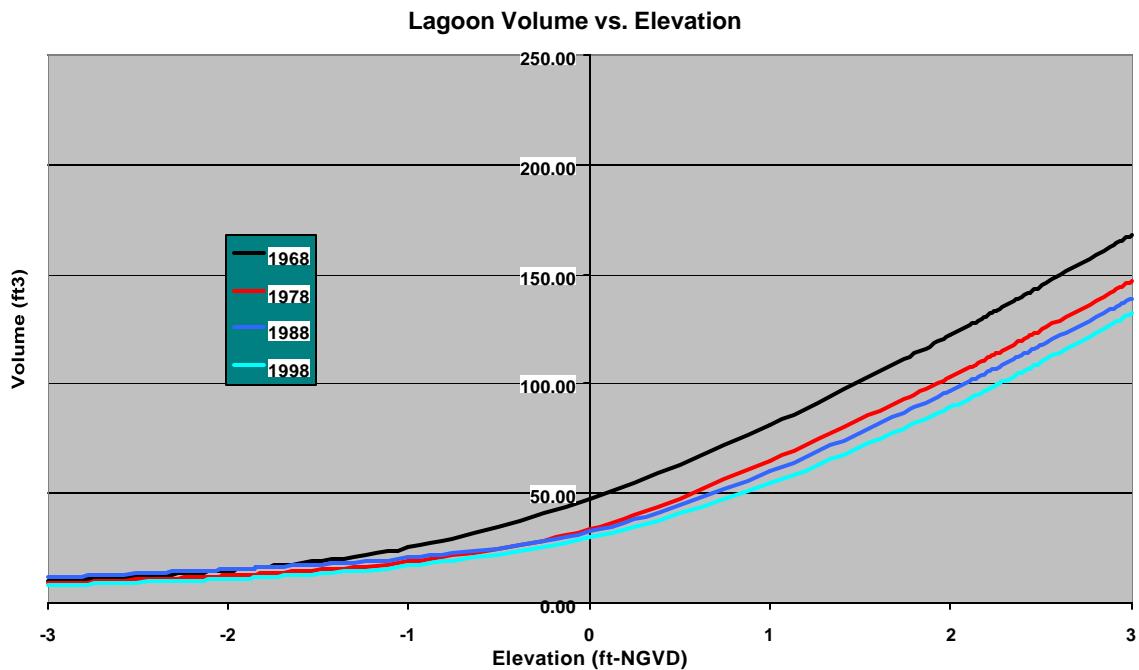


Figure 24 Lagoon Volume vs. Elevation

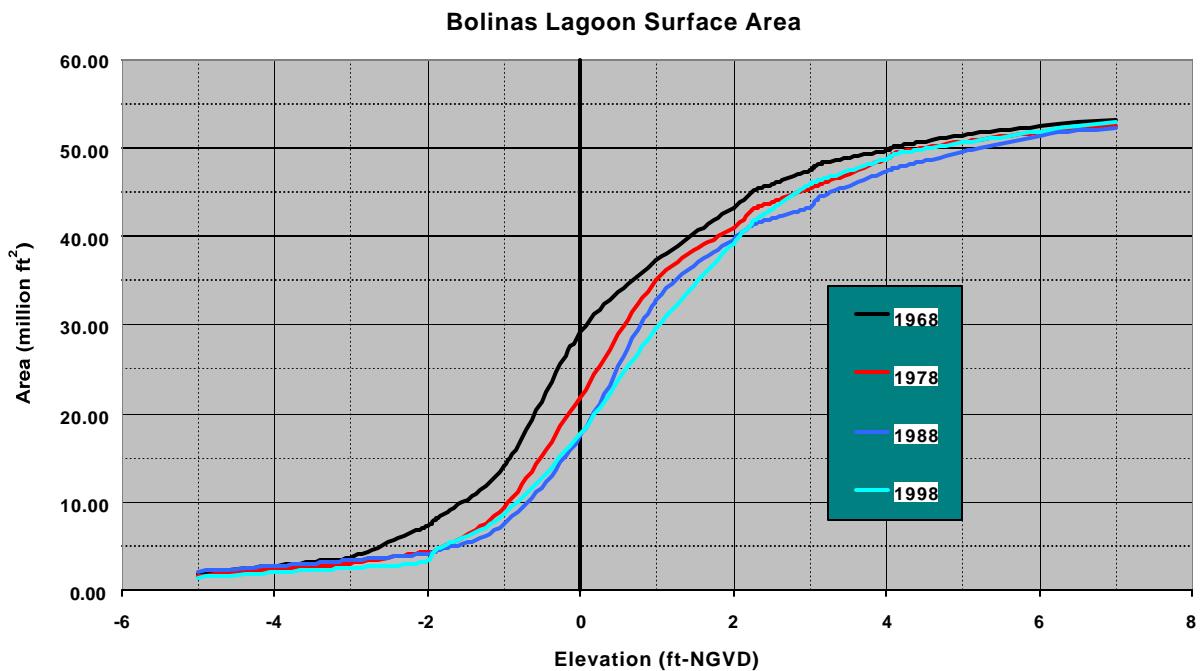


Figure 25 Surface Area vs. Elevation

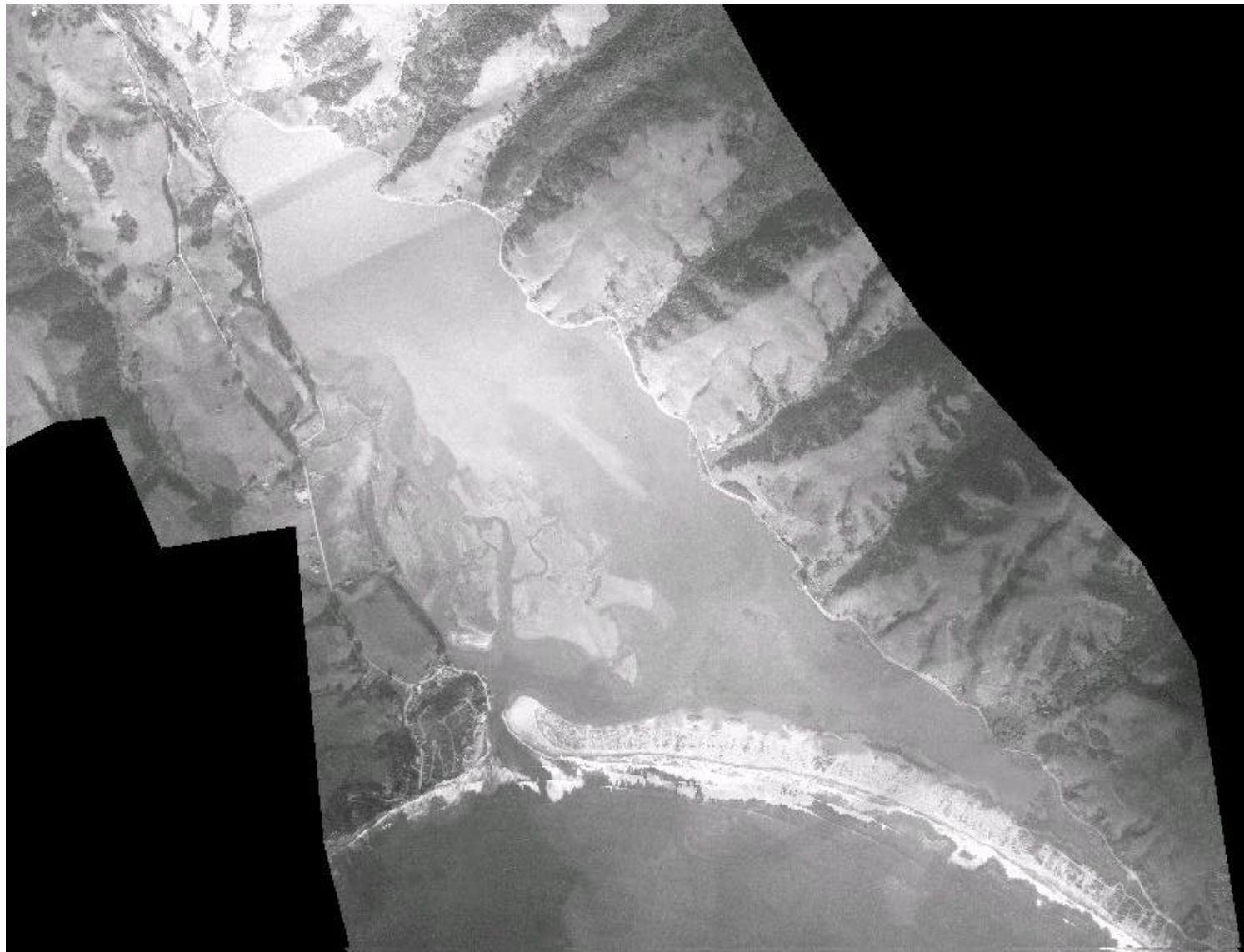


Figure 26 Bolinas Lagoon - 1942

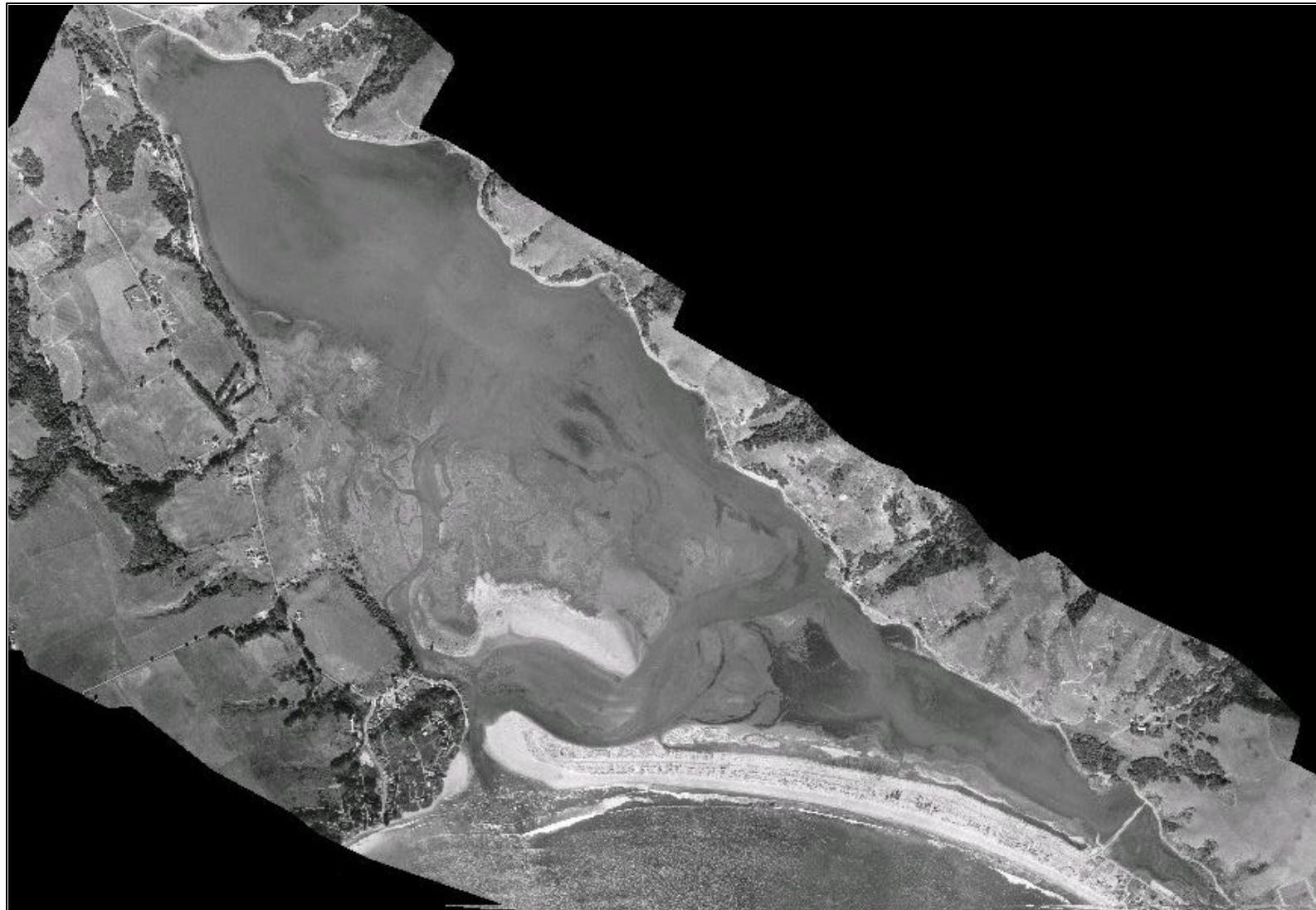


Figure 27 Bolinas Lagoon - 1959



Figure 28 Bolinas Lagoon - 1968



Figure 29 Bolinas Lagoon - 1984



Figure 30 Bolinas Lagoon - 1997

4.2 Diving Duck Habitat

To relate lagoon volume changes to the impacts on animal species in the lagoon, diving duck habitat acreage was calculated. Diving ducks feed at water depths between –2.70 ft and –8.70 ft NGVD. The diving duck habitat surface area was calculated in the same way as the subtidal, intertidal, and upland habitats. Figure 31 shows a decrease in diving duck habitat from 1968 to 1998.

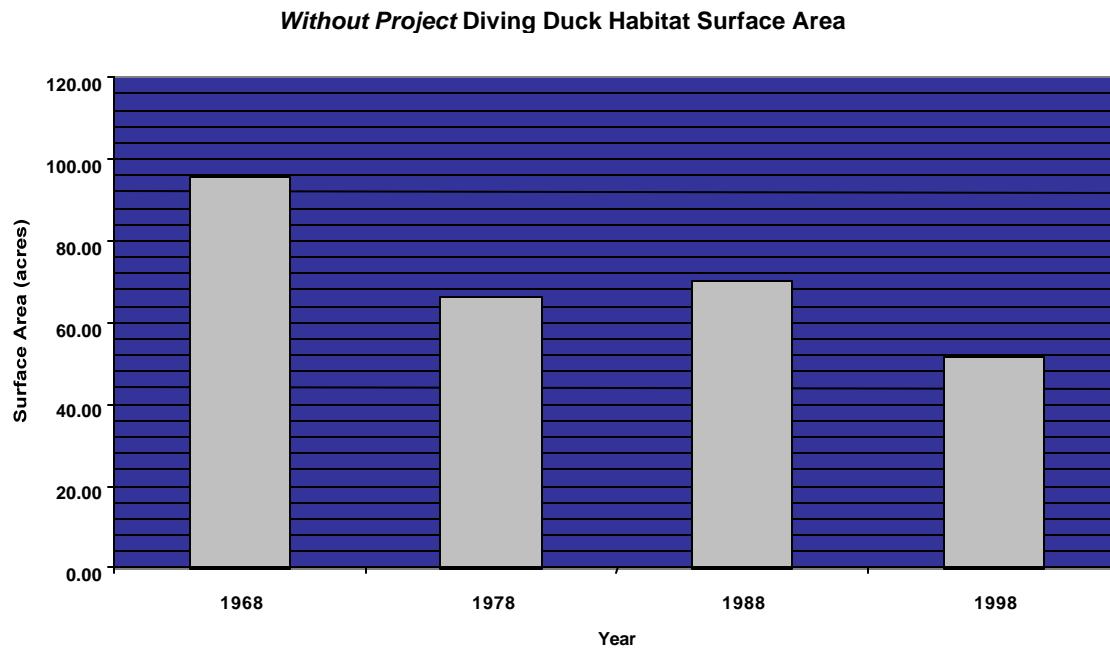


Figure 31 Lagoon Volume vs. Elevation

5 Lagoon Restoration Design Formulation

5.1 Restoration Design Methodology

The trends in the data thus far show a decrease in lagoon tidal volume over time, which results in a decrease in habitat for certain animal species such as diving ducks. Calculations also indicate that there is an increase in upland habitat, the area that remains above the water line at high tide during a typical spring tide (~3.15 ft NGVD). The likely cause for decreased lagoon tidal volume is the above average sedimentation rate. Therefore, restoration alternatives consist of sediment removal from various parts of the lagoon. These areas are referred to as restoration components.

5.2 Component Descriptions and Basis For Design

The components are defined and named after the specific lagoon feature that will be affected by the component. A location map, physical description, and design

methodology, are provided in this section for the individual components. The alternative descriptions, which are combinations of components, are provided in Section 5.3.

The design work was carried out using ArcView software. The 1998 bathymetry was manipulated by removing the 1998 data underneath the project footprint and replacing it with the designed bathymetry. ArcView 3-D and Spatial Analyst were used to calculate the dredge volumes.

There are nine areas being considered for sediment removal. The Pine Gulch Creek component has two variations that are treated separately, which leads to a total of ten individual components. Figure 32 is a map of the component locations. Figure 33 is a bathymetric map of the lagoon with all of the components displayed. Each component is denoted by a color border (color matches labeling in Figures 32 and 34). A summary of the footprint surface areas and dredge volumes is listed in Figure 32.

North Basin Component: In this alternative, the basin in the north end of the lagoon would be depended by 1.5' to 3' between the -1' NGVD and the -4' NGVD contours. Dredging a basin in this area would greatly increase intertidal and subtidal habitat, and it would also help maintain the Main Channel and Bolinas Channel. As shown in Figures 32 and 34, the North Basin would have a construction footprint of 136.11 acres and would remove 458,538 yds³. The material would be removed by hydraulic dredge and pumped through a pipeline to a barge moored in Bolinas Bay. The pipeline would most likely exit the lagoon across the tip of the Seadrift Sand Spit.

Main Channel Component: In order to provide sufficient flow to the north end of the lagoon, the Main Channel (channel between Kent Island and the Seadrift Sand Spit and adjacent to Highway One on the east side of lagoon) would be dredged at the locations indicated in Figures 32 and 33. Four sections of channel would be deepened or reestablished by removing between 1 and 4 ft of sediment and an island in the Main Channel. All channel sections with the exception of the most southerly channel section would be lowered to -3' NGVD with side slopes of 1V:3H. The southerly most section would be lowered to -4' NGVD with side slopes of 1V:3H. The area under the island would be lowered to an elevation of -4' NGVD. As shown in Figures 32 and 34, the Main Channel Component would have a construction footprint of 37.49 acres and would remove 216,241 yds³. Material would be removed by hydraulic dredge.

Highway One Fills Component: In this alternative, fill material would be removed along Highway 1. At each of the ten sites, material would be removed between a minimum elevation of 0' NGVD and a maximum elevation of 7' NGVD. These areas constitute unneeded turnouts, illegal disposal sites, excessive shoulder material, etc. From figures 32 and 34, the Highway One Fills Component would have a construction footprint of 3.25 acres and would remove 4,828 yds³. The material would be removed with land-based equipment.

Pine Gulch Creek Delta (Estuarine): This alternative will remove portions of the large deltaic formation on the west side of the lagoon. Approximately 1' to 2' of material will

be removed from the existing grade between the – 1.5' NGVD and 7' NGVD contours. This will require the removal of a portion of the existing riparian and wetlands habitat (7 out of 10 acres would be removed). The majority of the material will be removed with land-based equipment. A portion of the material (areas too deep to reach with land-based equipment) will be removed using a shallow hydraulic dredge. The material would be removed with a shallow hydraulic dredge.

Pine Gulch Creek Delta (Riparian): Approximately 1' to 2' of material will be removed from the existing grade between the – 1.5' NGVD and 4' NGVD contours. This will not require the removal of any of the 17 acres of the existing riparian habitat. The majority of the material will be removed with land-based equipment. A portion of the material (areas too deep to reach with land-based equipment) will be removed using a shallow hydraulic dredge.

Bolinas Channel Component: This alternative consists of dredging the channel that originates near the main inlet of the lagoon; flows between Kent Island and the town of Bolinas; continues to the north and terminates at the Pine Gulch Creek Delta (channel along East Bank of Bolinas Lagoon). Near the north end, the channel will diverge into two separate forks. This alternative will help to improve flow to the western side of the lagoon. As shown in the historical photos, the channel has experienced noticeable morphological changes (migrating significantly to the east) and has become very shallow and narrow. Bolinas channel will be dredged to a depth of –5.0' NGVD with side slopes of 1V: 3H, with the exception of the two forks, which will be dredged to a depth of –4.0' NGVD with side slopes of 1V: 3H. The material will be removed with a shallow draft hydraulic dredge.

Kent Island Component: As mentioned previously, Kent Island has grown significantly in size and elevation and now consists of a fairly large upland area with non-native plant/tree species. This alternative would restore the historical channel system through Kent Island that is evident in the 1942 photo (Figure 26). The main part of the channel will be 200' wide, have side slopes of 1V: 3H, and have a bottom elevation of -2.0' NGVD. In the northern portion of Kent Island, the channel will split into three sub channels, each with a width of 75', side slopes of 1V: 3H, and bottom elevations of -2.0' NGVD. The island will also be reduced in overall size by lowering its existing elevation by 1 to 2 feet. The material will be removed with a shallow hydraulic dredge. If the material is too dry it will be removed with land-based equipment. The land-based equipment used to remove the dry material would have to be brought in by barge or over a temporary bridge from Bolinas.

South Lagoon Channel Component: This channel would be constructed in the southeast portion of the lagoon. It would connect the main channel in the lagoon to the eastern set of culverts/channel of Seadrift Lagoon. The south lagoon channel would consist of a main portion that runs parallel to Dipsea Road and two branches that extend to the main channel. The extensions and main section would have a bottom elevation of -4' NGVD and side slopes of 1V:3H. The channel would be dredged using a shallow draft hydraulic dredge.

Dipsea Road Fill Component: In this alternative, fill material between the elevation of 0' and 7' NGVD along Dipsea Road would be removed. Because of regulations governing Bolinas Lagoon, septic tanks cannot be closer than 100' to the edge of the water. Therefore, to maintain water quality standards in Bolinas Lagoon, fill would only be removed from areas in excess of 100' from the road (possible edge of septic fields). The material at Dipsea Road would be removed with land-based equipment.

Seadrift Lagoon Component:

Variation 1: This alternative would open the now closed Seadrift Lagoon to full tidal flushing. This would be accomplished by replacing the existing culverts in the present locations with a total of six (6) concrete box culverts (each culvert would be 4'x6'). Three culverts would be placed at either end of the lagoon. Construction would be a limiting factor in the feasibility of this alternative. The current southeast location for the channel consists of a private lot, and it is unknown what footprint would be allowed there. Also, at the northwest end, the existing culverts run underneath a mature cypress tree as well as a portion of a private garage. Installation would require the removal of the tree and the structure. An option at this end of the lagoon would be to move the culverts to the boat ramp area directly adjacent to the existing culverts.

Variation 2: As an alternative to the culverts, one 20 foot-wide open channel could be installed at each end instead of the six culverts. The channel at the southeast end would follow the same path as the existing culverts and would require a bridge to be constructed on Dipsea Road. Land availability may be a limiting factor in the feasibility of this alternative. At the northwest end, the channel would be installed where the existing boat ramp is now. The boat ramp could be reconstructed at another location along Dipsea Road, or the open channel could be installed through a vacant lot. It might also be possible to use culverts at one end, and open channels at another.

Variation 3: Another option would be to use only one entrance channel or set of culverts at the northwest end. This option would open Seadrift Lagoon to tidal action, but only at the northern end. In other words, tidal water would come in and out of Seadrift Lagoon, but it would *not* flow through Seadrift Lagoon into the southern end of Bolinas Lagoon.

*Open channels at both ends are preferred by the Corps because of the ease of operation and maintenance, and because of potential additional environmental benefits resulting from having an open system. The culverts would be over 300 feet long, which does create maintenance issues, even with the larger box culverts. If erosion becomes an issue, a 1000-ft sheet pile wall would have to be installed near the lagoon inlets.

In order to ensure Seadrift Lagoon would be deep enough to provide the desired tidal flow, and to remove the copper sulfate contamination, dredging would have to be completed. To remove the copper sulfate, a sweeper dredge would be used. This type of dredge is capable of removing 6" to 12" of material from the bottom.

5.3 Alternative Description (Component Combinations)

The components are divided into three basic geographical areas (Figure 32). The alternatives are:

1. North - North Basin and Main Channel.
2. Central - Pine Gulch Creek Delta (Estuarine and Riparian), Bolinas Channel, Kent Island, and Highway One Fills.
3. South - South Lagoon Channel, Dipsea Road, and (With and Without Seadrift Lagoon).

This was done was to help keep the components that complimented each other hydraulically together. For example, the North Basin needs an adequate supply of water to fill it so the Main Channel was linked to it. Seadrift Lagoon was linked to the South Arm Channel since this would help provide water to the eastern opening of Seadrift Lagoon. Pine Gulch Creek Delta, Kent Island and Bolinas Channel were all linked because of their combined effects on the central part of the lagoon.

Furthermore, combining different components also reduces the number of alternative combinations. If each component was considered an alternative, the combinations of alternatives would be too numerous, making an analysis very difficult. With only three main restoration areas (plus variations of Pine Gulch Creek and exclusion of Seadrift from the South) the number of permutations was reduced to twelve (see Table 6).

Figure 36 shows the surface area and dredge volumes associated with each alternative. These numbers reflect the cumulative areas and volumes of the components that are included in each alternative.

Table 6. Restoration Alternatives

North and South (no Seadrift)	North and Central (Estuarine)	Central (Riparian) and South (no Seadrift)	North, Central (Riparian), and South (no Seadrift)
North and South (Seadrift)	Central (Riparian) and South (Seadrift)	Central (Estuarine) and South (no Seadrift)	North, Central (Estuarine), and South (Seadrift)
North and Central (Riparian)	Central (Estuarine) and South (Seadrift)	North, Central (Riparian), and South (Seadrift)	North, Central (Estuarine), and South (no Seadrift)

Component Footprint Areas and Dredge Volumes

Component	Surface Area acres	Volume ³ yds
Bolinas Channel	15.57	130,799
Pine Gulch Creek Delta (Estuarine)	102.82	190,706
Pine Gulch Creek Delta (Riparian)	86.32	158,617
Dipsea Road	7.97	37,692
Highway 1 Fills	3.25	4,828
Kent Island	124.06	376,748
Seadrift Lagoon	43.47	44,958
South Lagoon Channel	17.58	89,246
Main Channel	37.49	216,241
North Basin	136.11	458,538

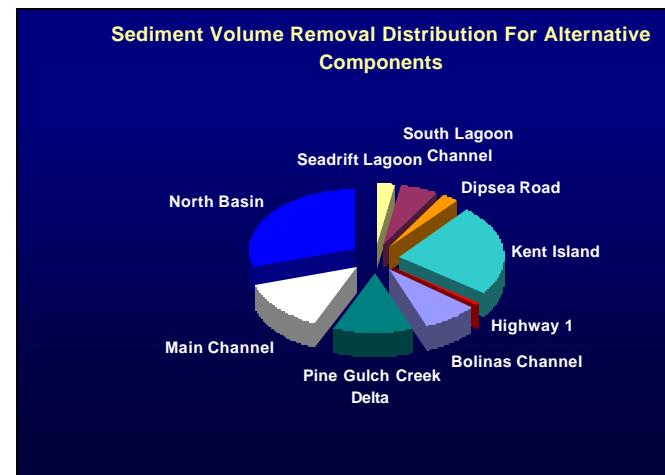
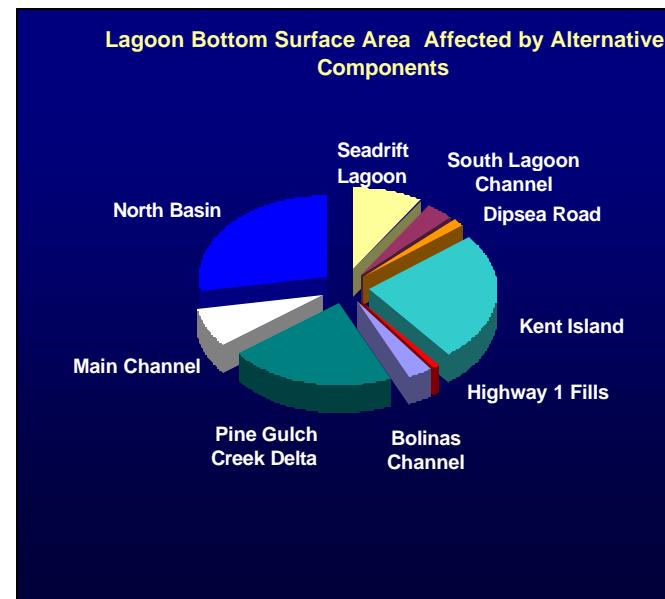
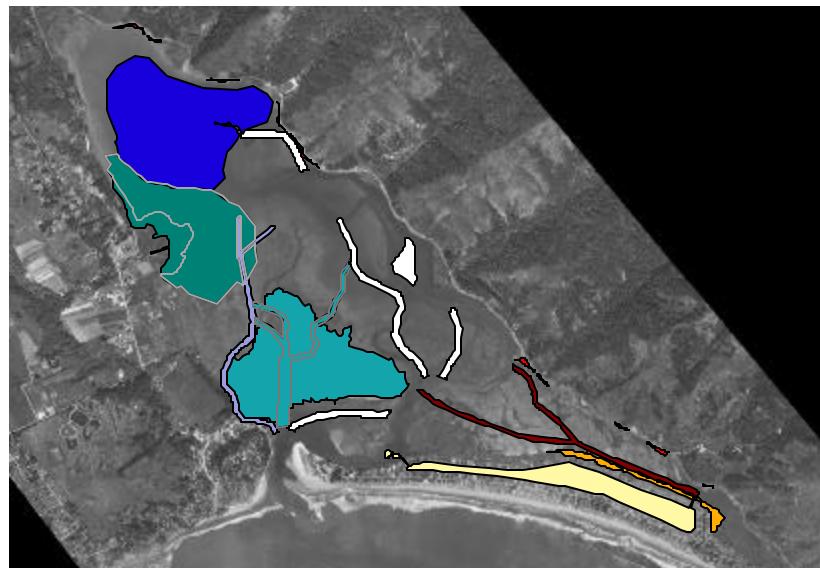


Figure 32 Component Footprint and Surface Area and Dredge Volume

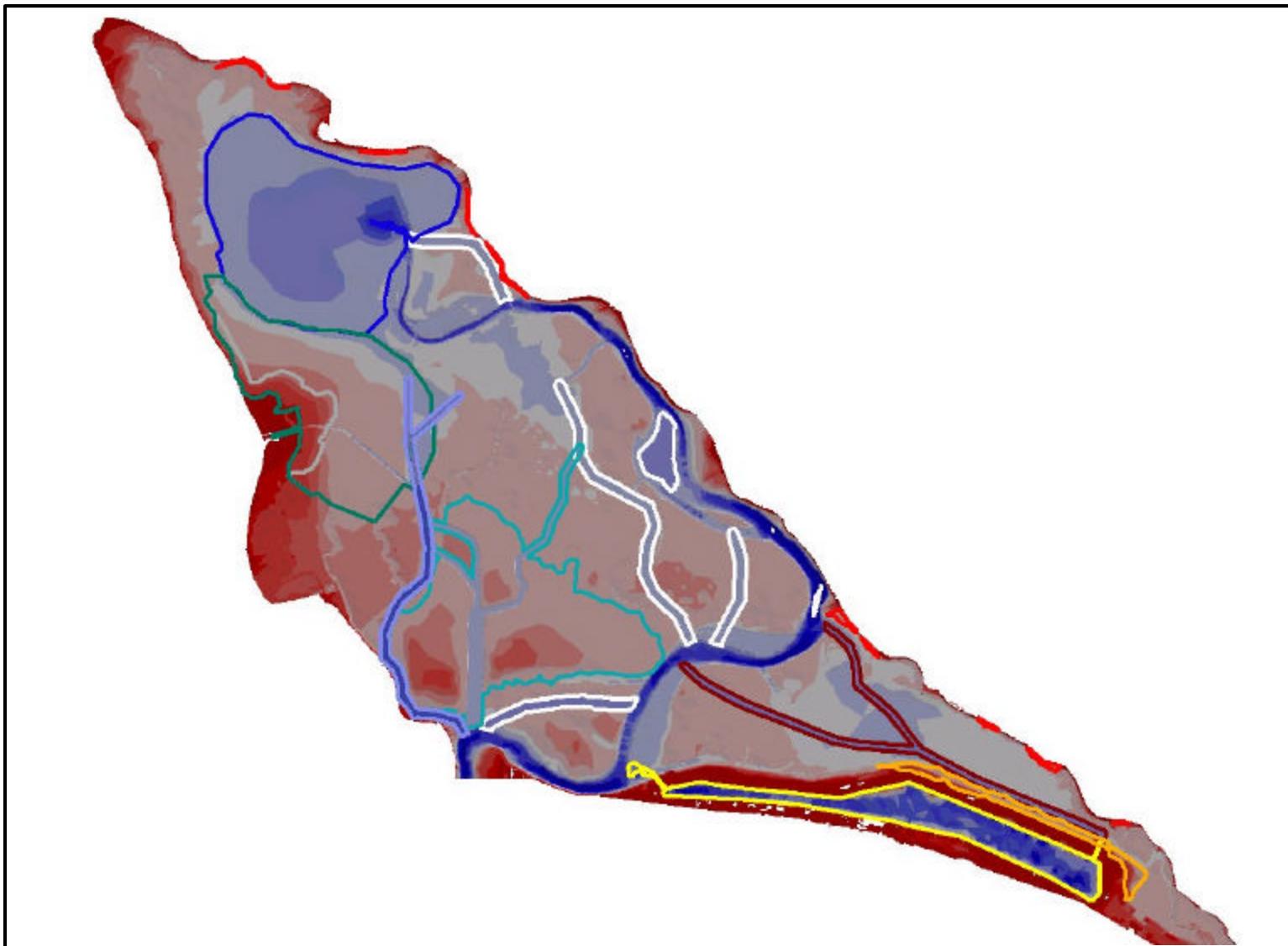


Figure 33 Bathymetric Map With Outlined Components

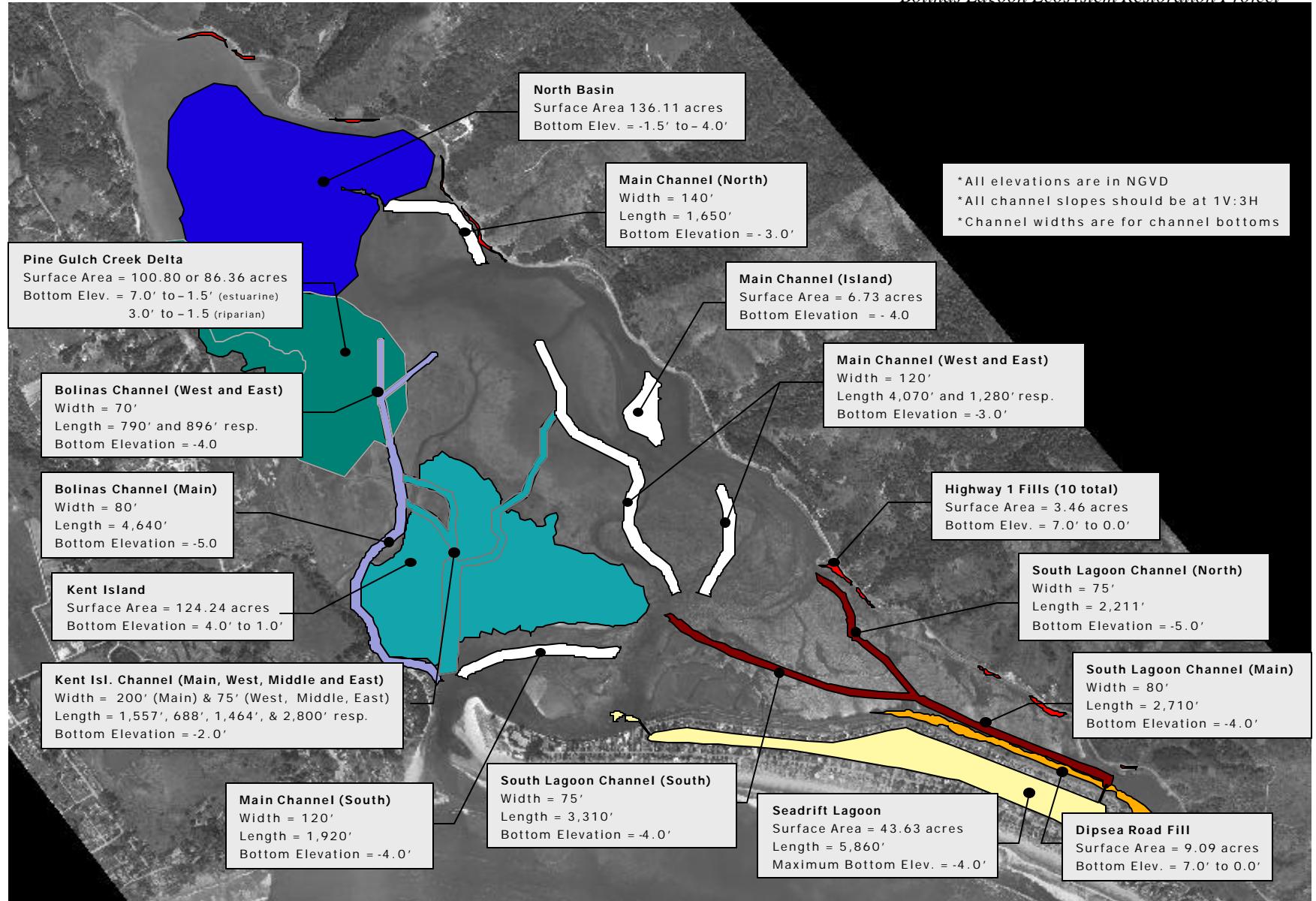


Figure 34 Component Locations and Brief Descriptions

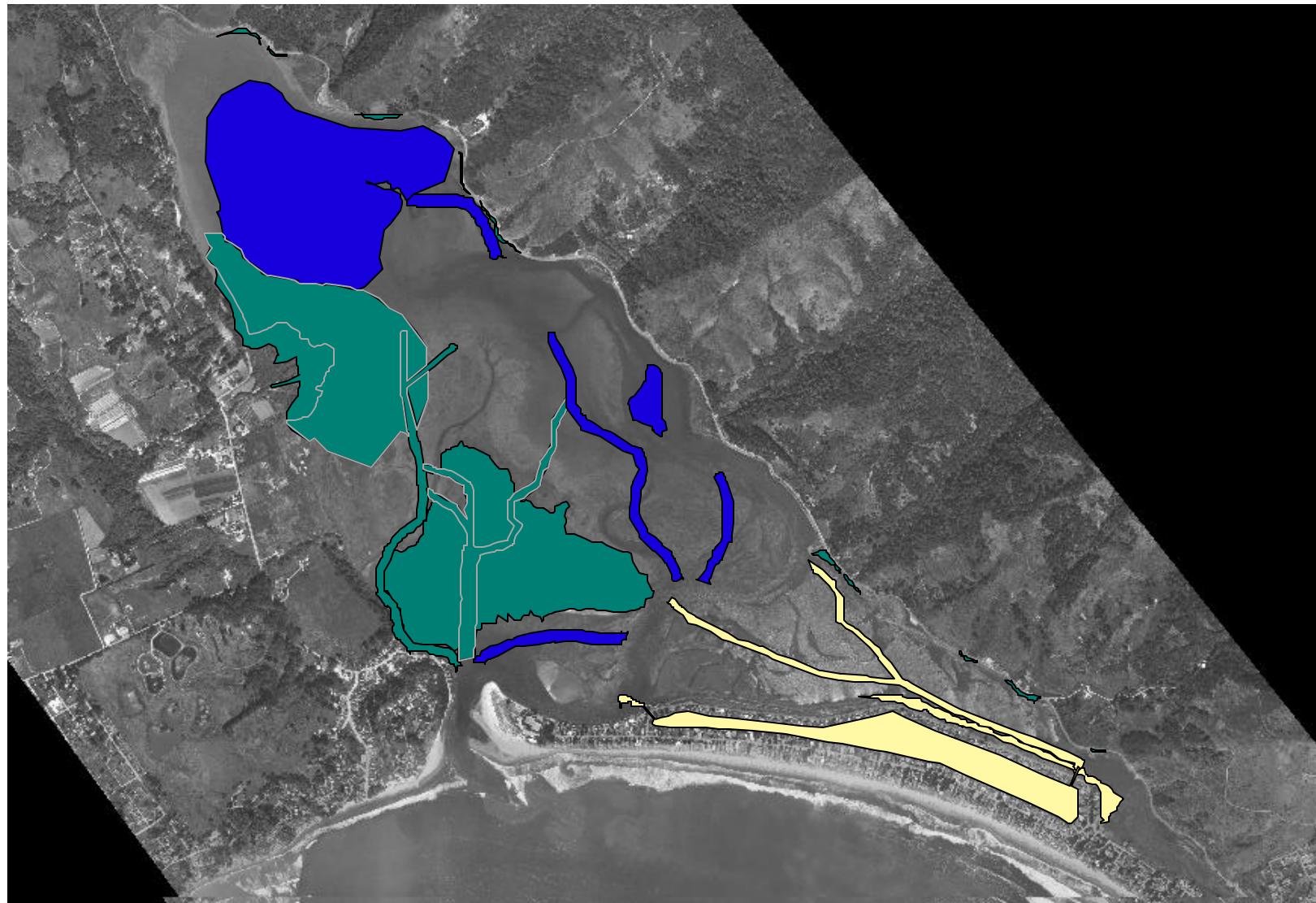


Figure 35 Map of Basic Geographic Areas

Alternative Footprint Areas and Dredge Volumes

Alternative	Surface Area acres	Dredge Volume yds ³
North	173.60	674,778
Central (Estuarine)	245.71	703,081
Central (Riparian)	229.20	670,993
South (Seadrift)	69.02	171,897
South (No Seadrift)	25.55	126,939
North and Central (Estuarine)	419.31	1,377,860
North and Central (Riparian)	402.80	1,345,771
North and South (Seadrift)	242.62	846,675
North and South (No Seadrift)	199.15	801,717
Central (Estuarine) and South (Seadrift)	314.73	874,978
Central (Estuarine) and South (No Seadrift)	271.26	830,020
Central (Riparian) and South (Seadrift)	298.22	842,889
Central (Riparian) and South (No Seadrift)	254.75	797,931
North, Central (Estuarine), and South (Seadrift)	488.33	1,549,757
North, Central (Estuarine), and South (No Seadrift)	444.86	1,504,799
North, Central (Riparian), and South (Seadrift)	471.82	1,517,668
North, Central (Riparian), and South (No Seadrift)	428.35	1,472,710

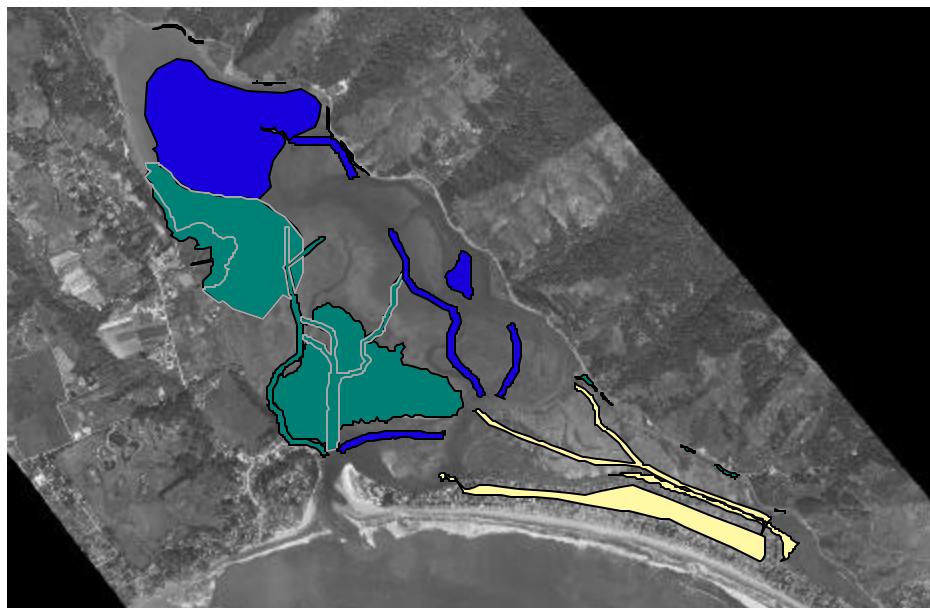
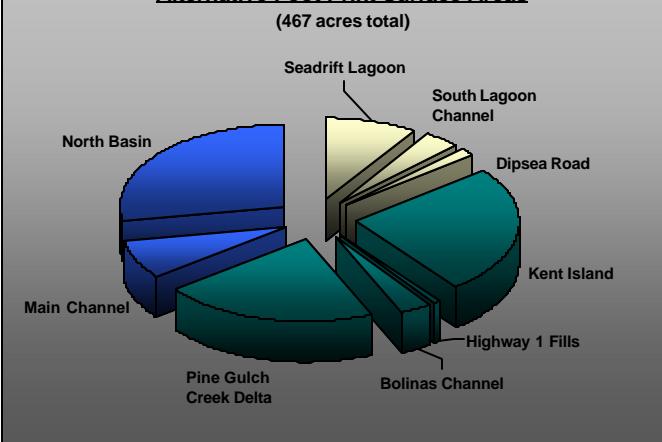


Figure 36 Alternative Footprint and Dredge Volumes

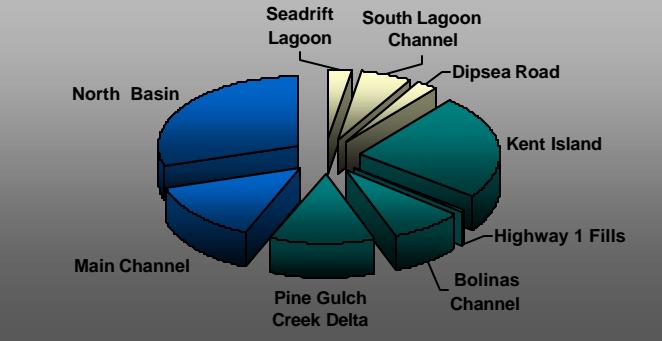
Alternative Foot Print Surface Areas



*Note - the pi chart only reflects the alternatives with the unmodified components.

Alternative Dredge Volume

(1.54 million cubic yards total)



*Note - the pi chart only reflects the alternatives with the unmodified components.

6 Future (With Project) Lagoon Physics

6.1 Lagoon Volume

Figures 37 and 38 show future lagoon volumes for spring and neap tides for the NER and LPP alternatives and the *without project* conditions. The future lagoon volumes for the various alternatives were determined in ArcView. The NER and LPP would create nearly identical lagoon volumes (volume plot lines are overlapping). For these two alternatives the lagoon volume would be greater than the 1968 volume after construction.

Considering the implementation of the alternatives, the time frame for the lagoon to return to its 1998 conditions was estimated. The estimation predicts that the lagoon will return to the 1998 volume around the year 2080 (assuming 0.50 million ft³/yr infill rate).

6.2 Tidal Prism

The potential spring and neap tidal prism for LPP and NER plans was calculated using the same methodology as that which was used for the *without project* tidal prism. Recall that the tidal prisms were calculated by multiplying the future lagoon volumes by an effective/potential tidal prism ratio. The data is plotted in Figures 39 and 40. The figures show that the tidal prism is increased with dredging, as opposed to without project estimates. The North, Central, and South (no Seadrift) alternatives are nearly identical for both spring and neap tide conditions. All alternatives and *without project* conditions show a decrease in tidal prism over time.

6.3 Water Surface Elevations

The future lagoon volumes for each alternative were used to calculate the water surface elevations for spring and neap tides. The volumes were multiplied by ratios to compute the elevations. The lagoon elevations used in the ratio calculations are the maximum and minimum water surface elevations in the lagoon for a specific date. These numbers are an average of the water elevations for the North and South portions of the lagoon.

The water surface elevations for the two plans are plotted separately in Figures 41 and 42. Both alternatives have higher water surface elevations than the *without project* conditions. The water surface elevations decrease over time. The spring and neap tide water surface elevations for the two plans are compared in Figures 43 and 44.

Lagoon Volume (Spring High Tide)

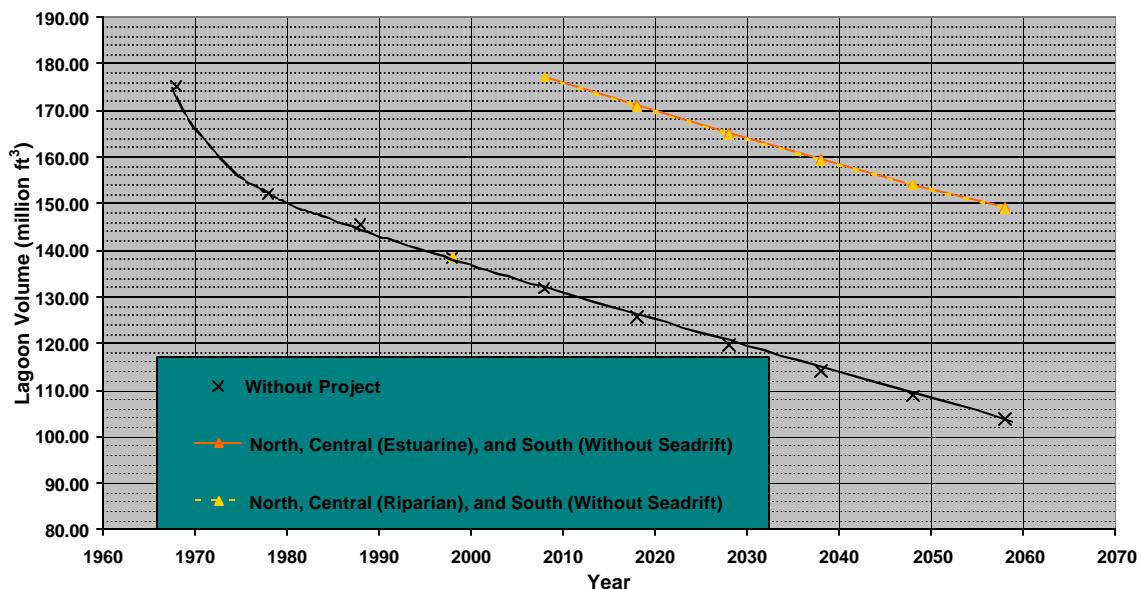


Figure 37 With Project Future Lagoon Volumes (Spring Tide)

Lagoon Volume (Neap High Tide)

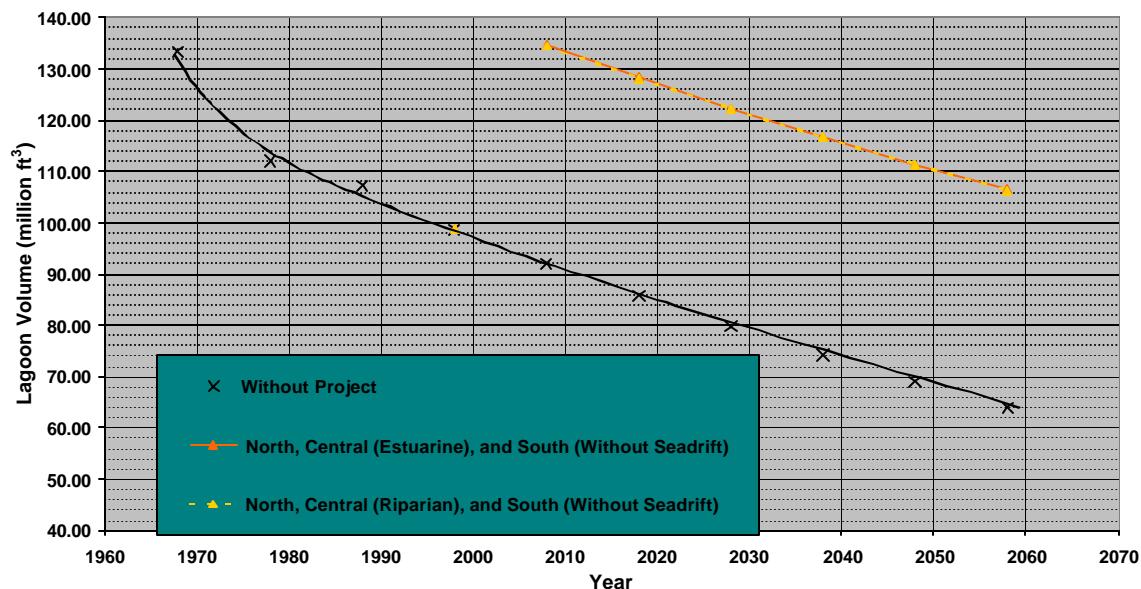


Figure 38 With Project Future Lagoon Volumes (Neap Tide)

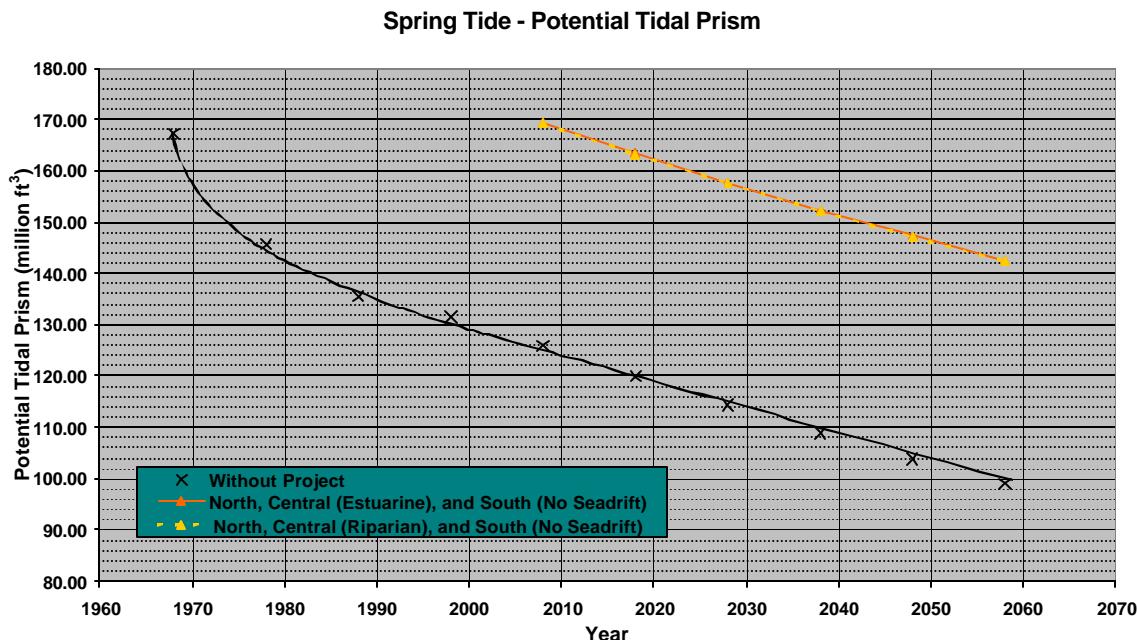


Figure 39 With Project Spring Tide Potential Tidal Prism

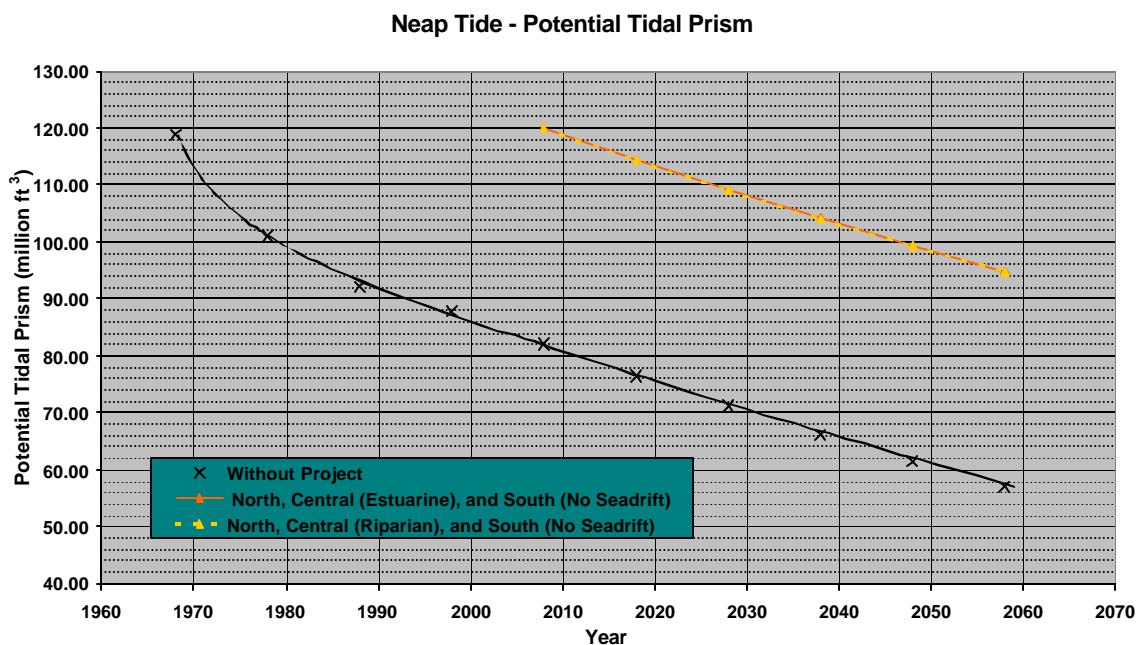


Figure 40 With Project Neap Tide Potential Tidal Prism

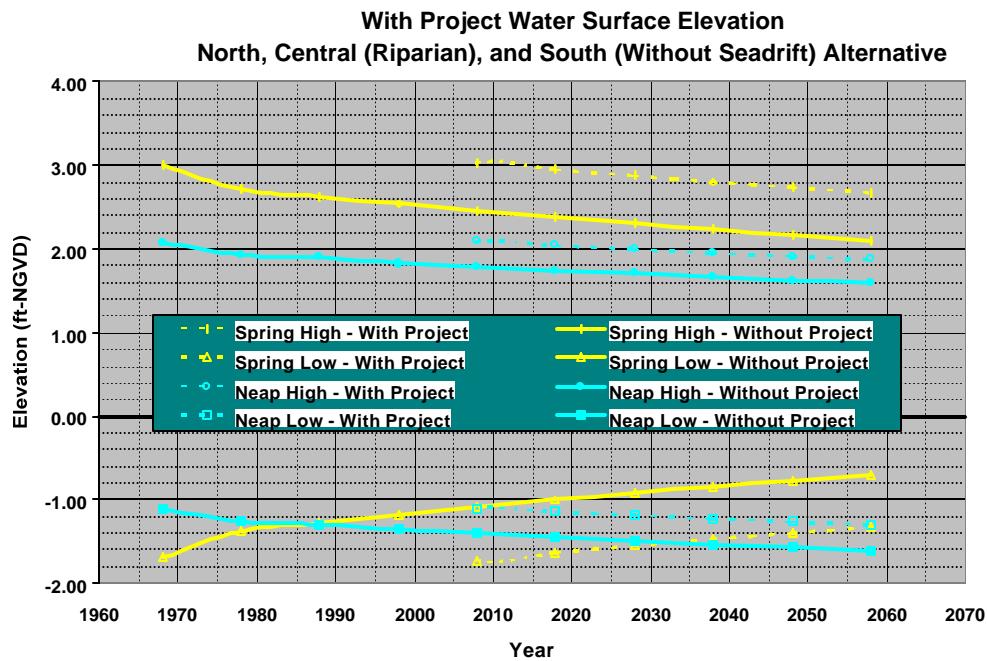


Figure 41 With Project Water Surface Elevation for the LPP

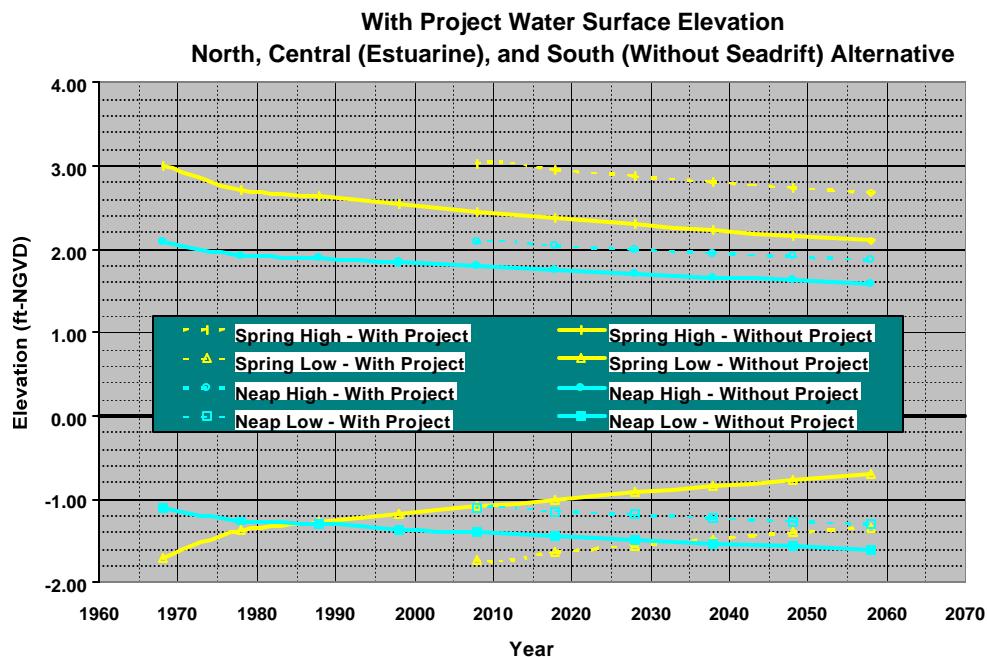


Figure 42 With Project Water Surface Elevation for the NER Plan

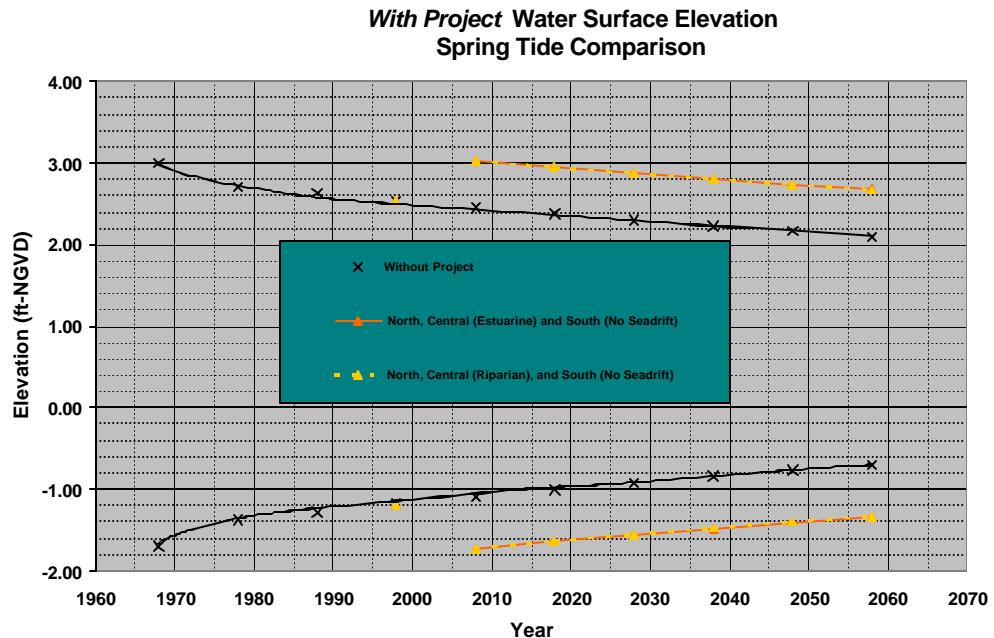


Figure 43 With Project Water Surface Elevation: Spring Tide Comparison

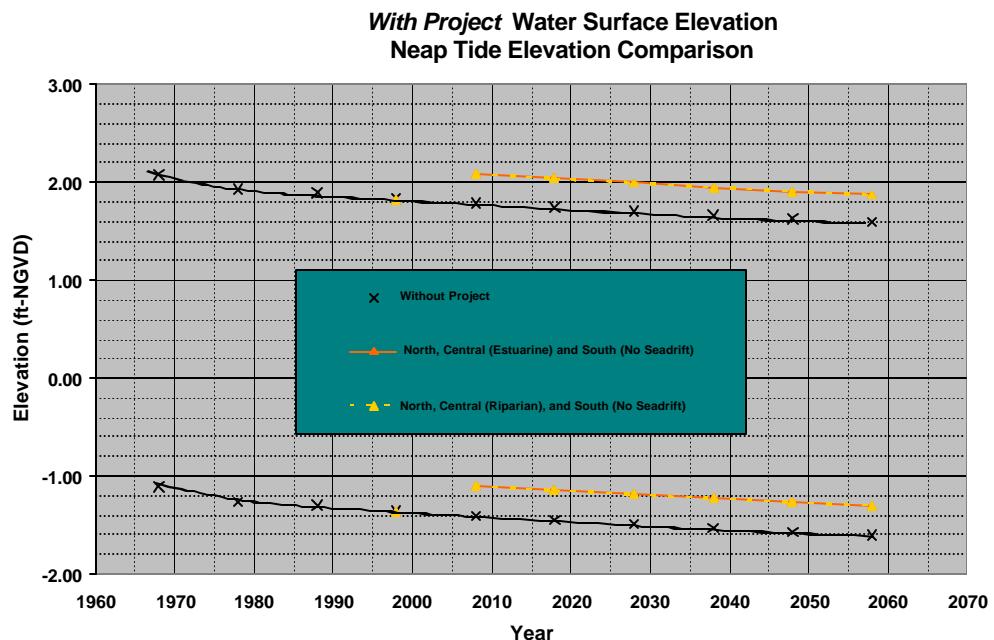


Figure 44 With Project Water Surface Elevation: Neap Tide Comparison

6.4 Inlet Stability

As previously mentioned, one of the indicators of inlet stability is the closure index. The closure index was calculated for a 50-year time period for all 12 alternatives, as depicted by Table 7. The four main scenarios are highlighted in yellow. For the NER and LPP

plans, inlet closure would not be a factor until the year 2125 (assuming that construction was finished in 2008). In the *without project* condition, under a worst-case scenario, the inlet could close by 2050. A worst-case scenario is characterized by large storm waves and low fresh water input during a neap tidal cycle (low tidal flow through inlet).

Table 7. Inlet Closure Index Summary

Alternative	Year				
	1998	2008	2018	2038	2058
<i>Without Project</i>	10.5	11.2	12.0	13.9	16.1
Central (Estuarine) and South (Seadrift)		8.4	8.5	9.4	10.4
Central (Estuarine) and South (No Seadrift)		9.0	9.4	10.5	11.7
Central (Riparian) and South (Seadrift)		8.4	8.5	9.5	10.4
Central (Riparian) and South (No Seadrift)		9.0	9.4	10.5	11.8
North and South (Seadrift)		8.5	8.2	9.0	9.9
North and South (No Seadrift)		9.0	9.0	10.0	11.1
North and Central (Estuarine)		8.2	8.2	9.1	10.0
North and Central (Riparian)		8.2	8.2	9.1	10.0
North, Central (Estuarine), and South (Seadrift)		7.6	7.4	8.1	8.8
North, Central (Estuarine), and South (No Seadrift)		8.1	8.0	8.8	9.7
North, Central (Riparian), and South (Seadrift)		7.6	7.4	8.1	8.8
North, Central (Riparian), and South (No Seadrift)		8.1	8.0	8.8	9.7

6.5 Habitat Volume and Surface Area Comparison

Recall from Section 4 that the three types of habitats defined for Bolinas Lagoon are upland, intertidal, and subtidal. The future volumes and surfaces areas of all three habitats were quantified and summarized in Figures 45 through 49 for all the alternatives. All alternatives show an increase in habitat. The alternatives with three components show the largest increase in habitat. Section 6.6 discusses the future habitat projection methodology in greater detail.

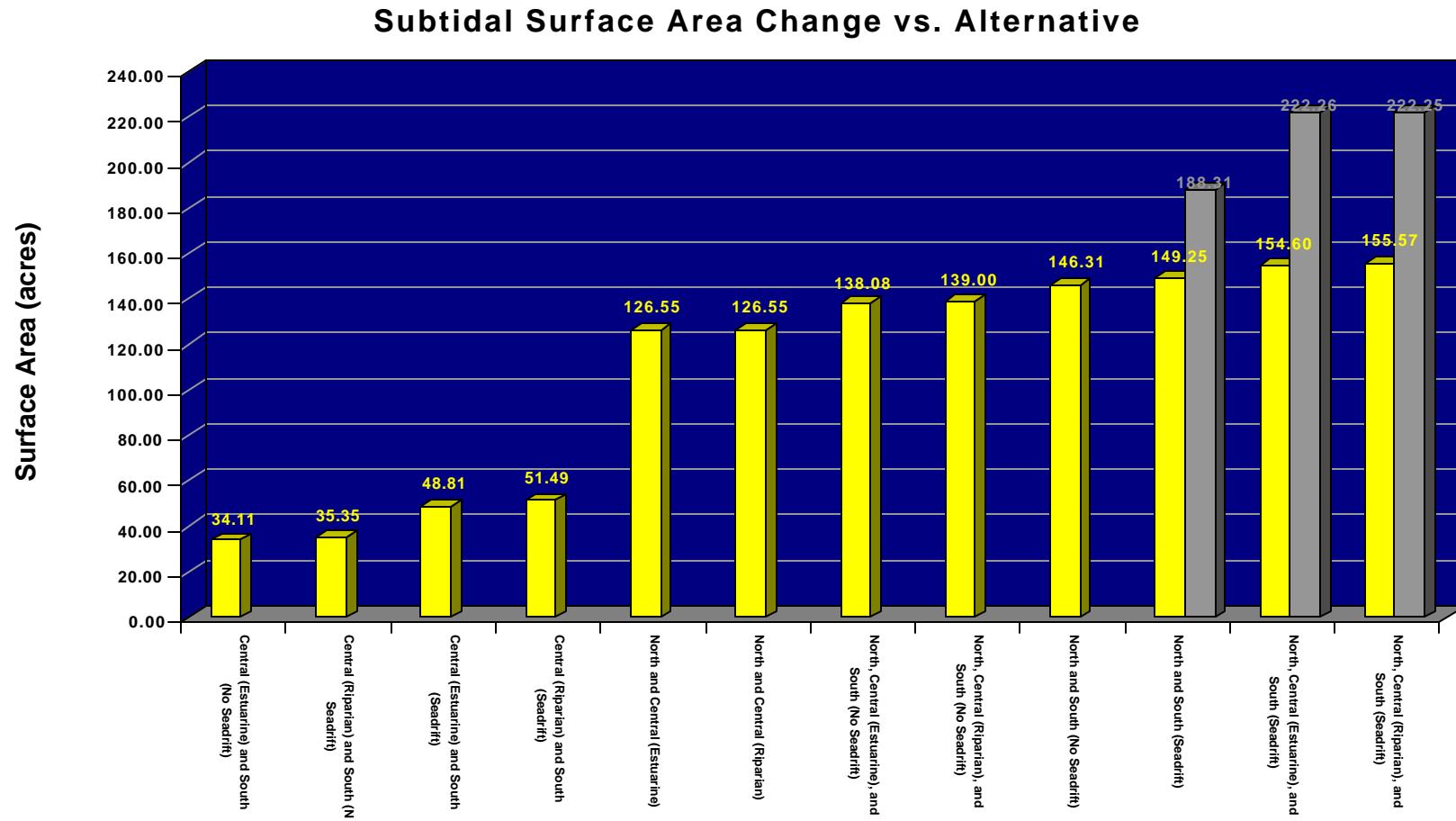


Figure 45 Change in Subtidal Surface Area for Each Alternative

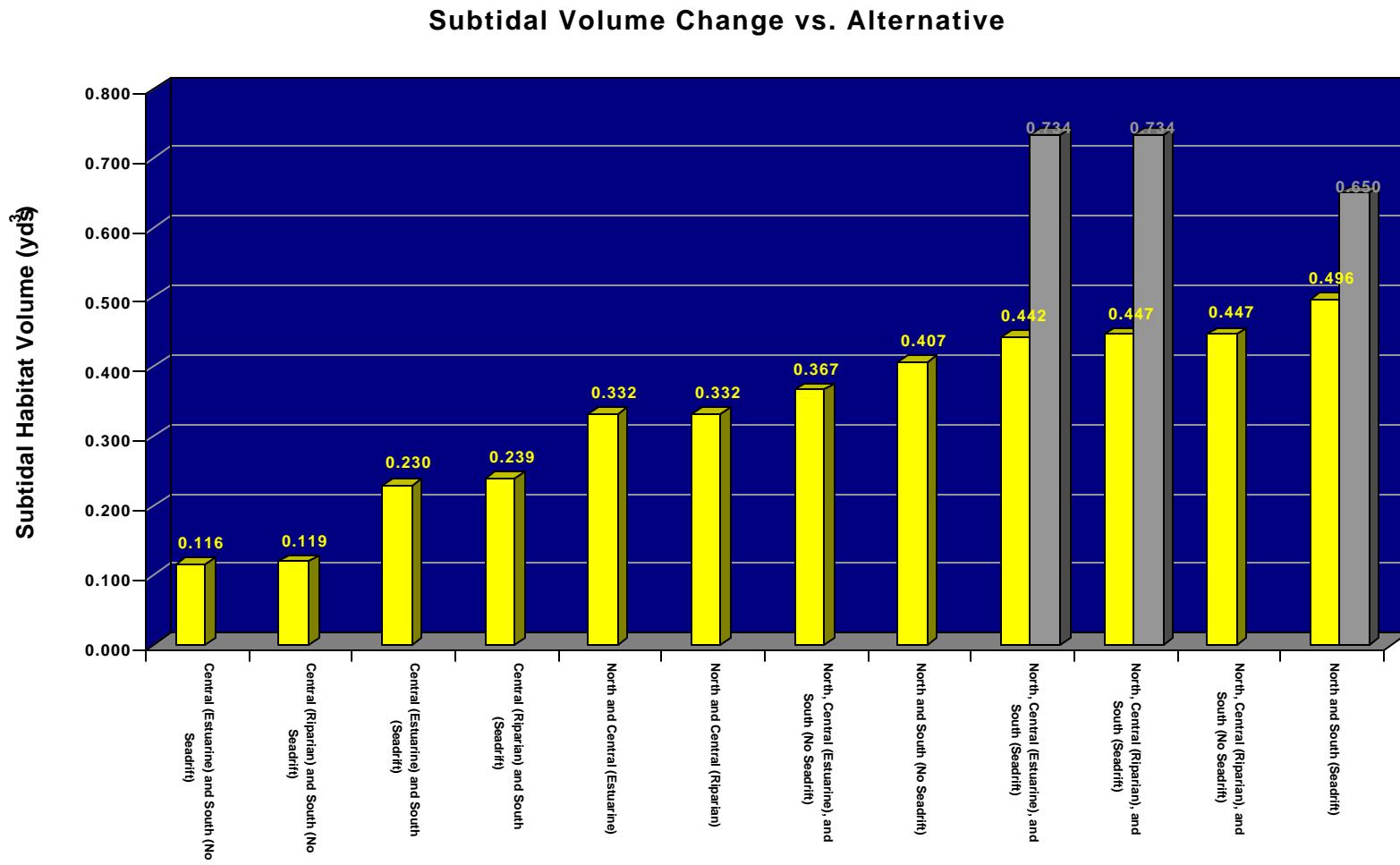


Figure 46 Change in Subtidal Volume for Each Alternative

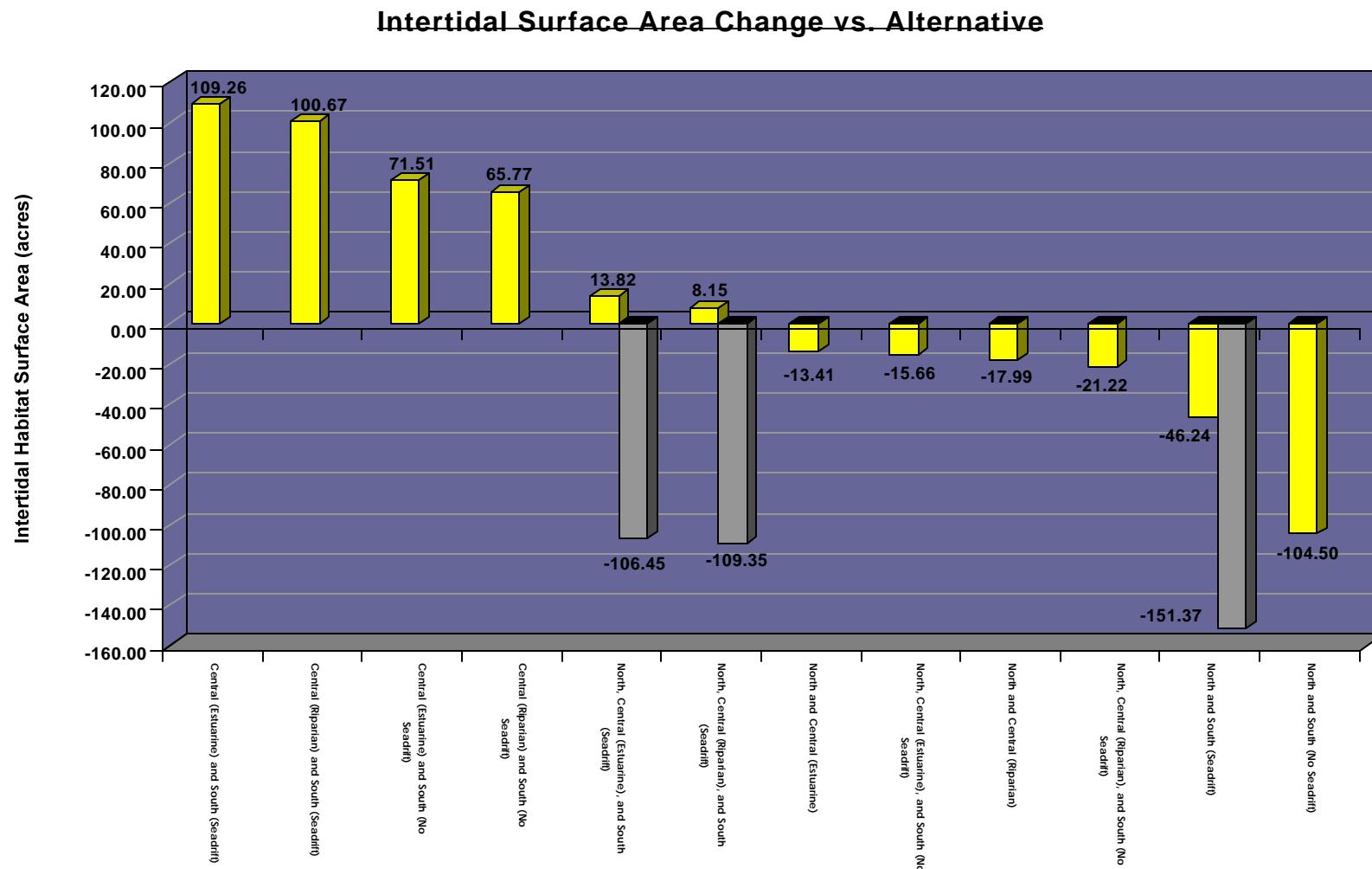


Figure 47 Change in Intertidal Surface Area for Each Alternative

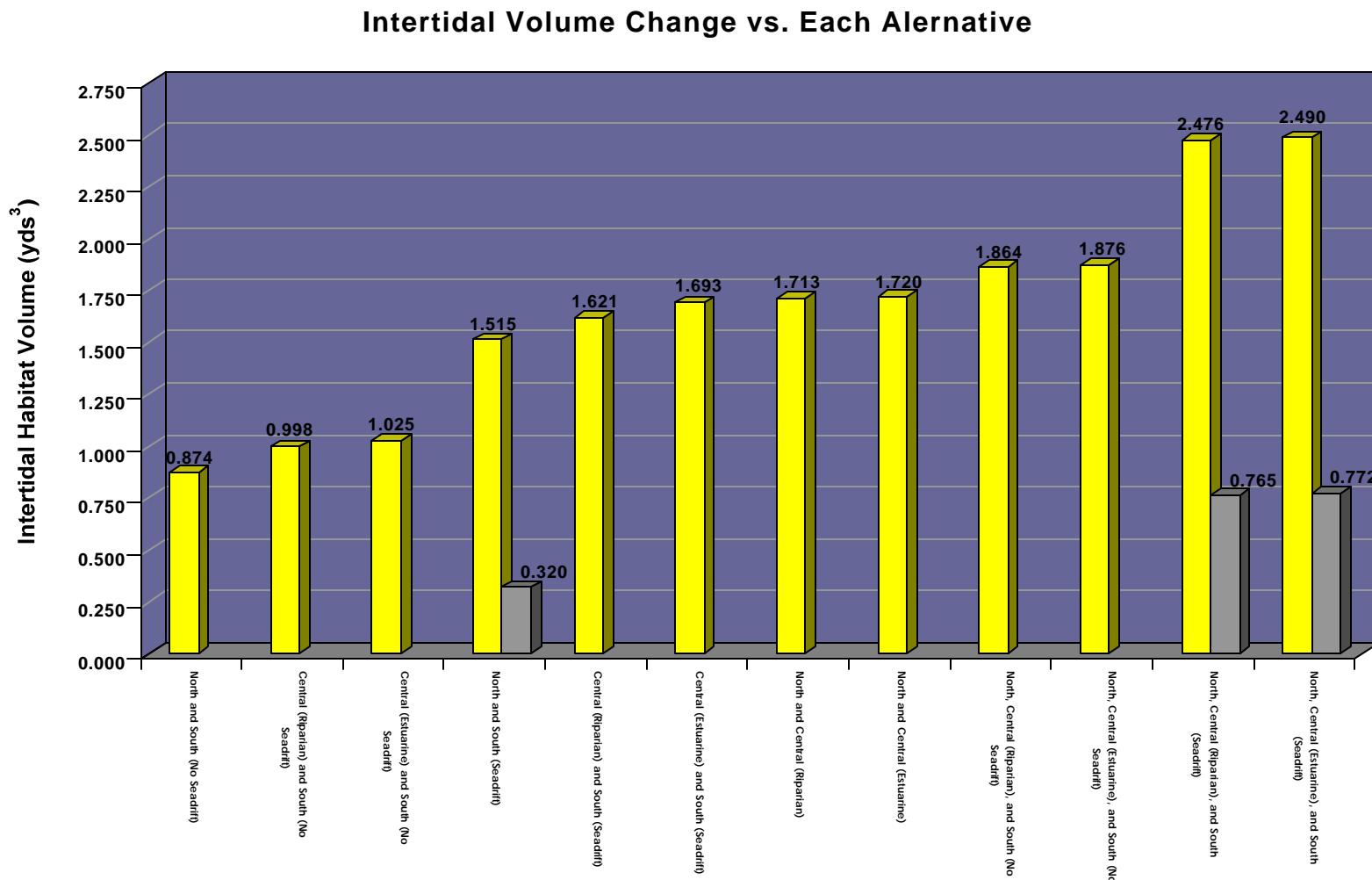


Figure 48 Change in Intertidal Volume for Each Alternative

Upland (no tidal contribution) Surface Change Area vs. Alternative

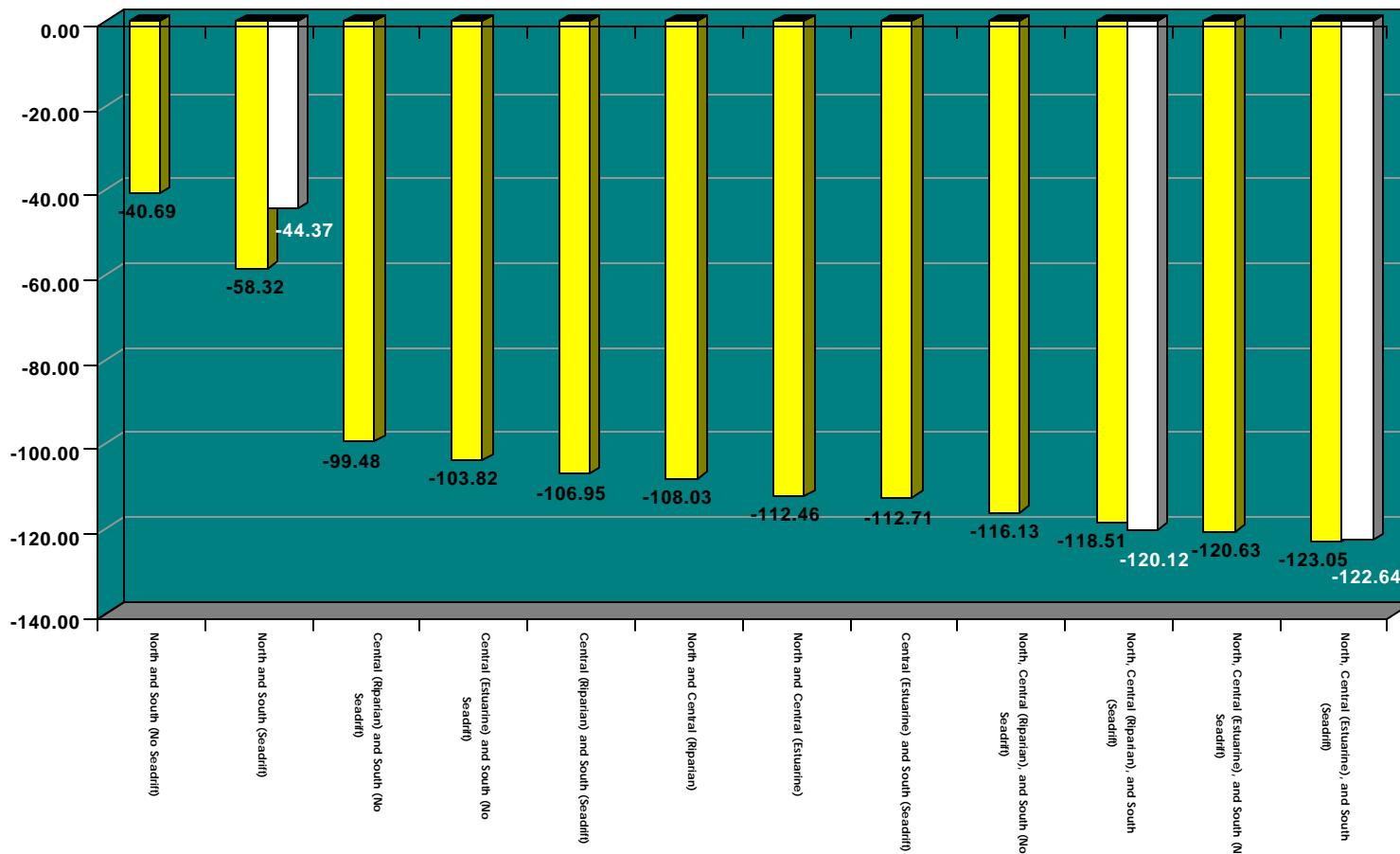


Figure 49 Change in Upland Surface Area for Each Alternative

6.6 50-Year With Project Habitat Projection

In order to determine future habitat levels for various alternatives, future lagoon volumes were used. Recall that these volumes were determined in ArcView using bathymetry data. Nine different water levels (all referenced to NGVD) were identified:

- Spring low potential (-3.45 ft)
- Neap low potential (-2.05 ft)
- Predicted Low (varies)
- 1998 Low (-1.36 ft)
- Neap high (potential) (2.25 ft)
- 1998 high (2.54 ft)
- Predicted high (varies)
- Spring high (potential) (3.15 ft)
- Upper bound (7 ft)

The upland habitat is the predicted high water volume subtracted from the upper bound water volume. The intertidal water volume is the predicted low water volume subtracted from the predicted high water volume. The subtidal volume is the predicted low water volume.

The habitat levels associated with *without project* conditions and the LPP and NER plans are listed in Tables 8 through 10, and the corresponding information is plotted in Figures 50 through 54. In Table 9, lagoon volume and subtidal acreage decrease over time. Upland acreage increases. Intertidal habitat increases by the year 2018 and then begins to decrease. The same trends are observed in Table 10. Upland habitat does increase over time for both alternatives, but there would be less upland habitat in 2058 as compared to *without project* conditions. Both plans show increased habitat area as compared to *without project* conditions.

Figure 50 shows that the conversion of intertidal habitat to upland habitat is not as great as the *without project* conditions indicate. Figures 51 and 52 show an increase in intertidal habitat and than a decrease over time, as noted in the preceding paragraph. Figures 53 and 54 show a sharp decrease in subtidal habitat between 2008 and 2018. The trend of decreasing subtidal habitat continues after this point in a much more gradual manner.

6.7 Diving Duck Habitat Levels

Figure 55 shows the diving duck habitat surface area in acres for all 12 alternatives. The four alternatives result in an increase of surface area as compared to 1968 and 1998.

Table 8. Without Project Habitat Projections (No Action)

Year	Lagoon Volume yd^3	Upland acres	Upland yd^3	Intertidal acres	Intertidal yd^3	Subtidal acres	Subtidal yd^3
2008	4,883,508	252.77	8,351,980	843.61	3,228,889	134.45	502,281
2018	4,652,007	266.74	8,455,354	838.92	2,890,014	123.07	482,246
2038	4,223,741	292.59	8,646,590	830.25	2,263,112	102.03	445,183
2058	3,841,791	315.64	8,817,144	822.52	1,704,008	83.26	412,128

Table 9. North, Central (Estuarine), and South (No Seadrift) Alternative Habitat Projection.

Year	Lagoon Volume ³ yds	Upland acres	Upland ³ yds	Intertidal acres	Intertidal ³ yds	Subtidal acres	Subtidal ³ yds
2008	6,567,513	117.47	7,568,491	832.87	5,460,468	284.47	890,366
2018	6,336,011	165.11	7,703,385	873.01	5,355,085	205.82	627,984
2038	5,907,745	190.96	7,894,621	864.34	4,728,183	184.78	590,921
2058	5,525,796	214.01	8,065,175	856.61	4,169,080	166.01	557,866

Table 10. North, Central (Riparian), and South (No Seadrift) Alternative Habitat Projection

Year	Lagoon Volume ³ yds	Upland acres	Upland ³ yds	Intertidal acres	Intertidal ³ yds	Subtidal acres	Subtidal ³ yds
2008	6,559,185	121.97	7,547,720	827.31	5,448,416	285.39	894,995
2018	6,327,684	165.61	7,707,103	872.84	5,342,896	205.41	627,264
2038	5,899,418	191.46	7,898,339	864.17	4,715,994	184.37	590,201
2058	5,517,469	214.51	8,068,894	856.44	4,156,891	165.60	557,146

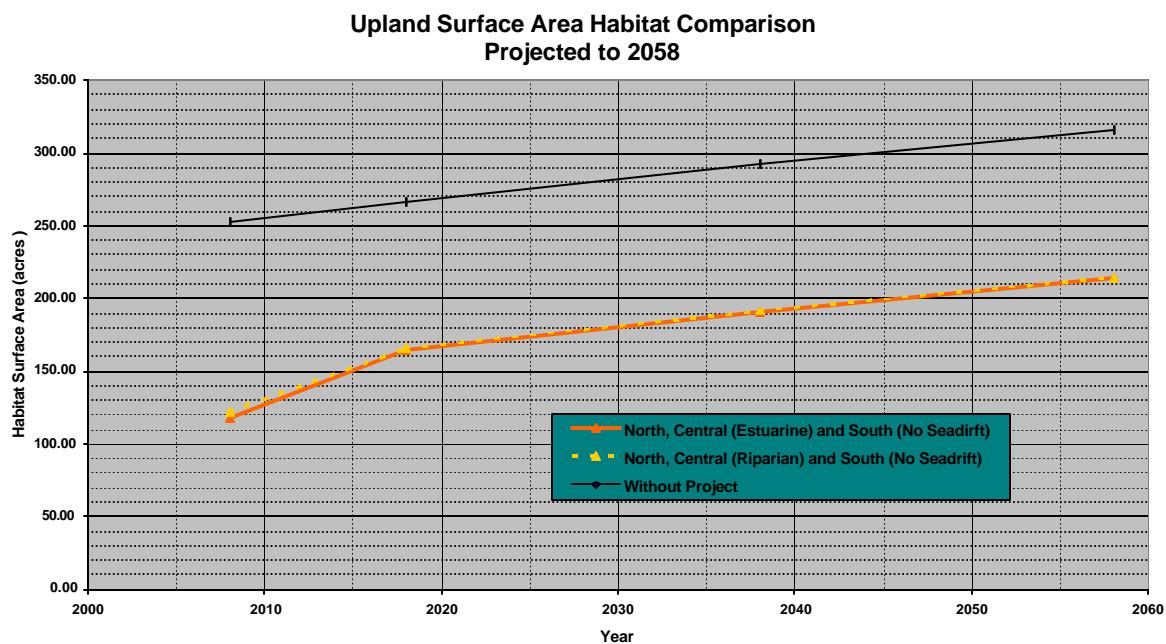


Figure 50 With Project Upland Habitat Surface Area Projection

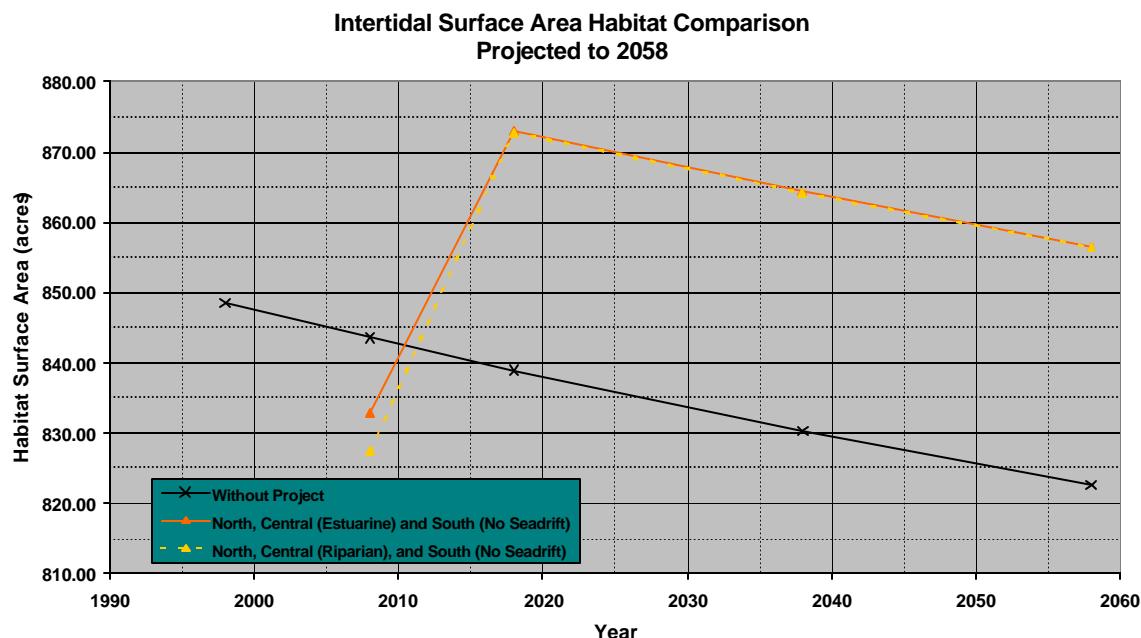


Figure 51 With Project Intertidal Habitat Surface Area Projection

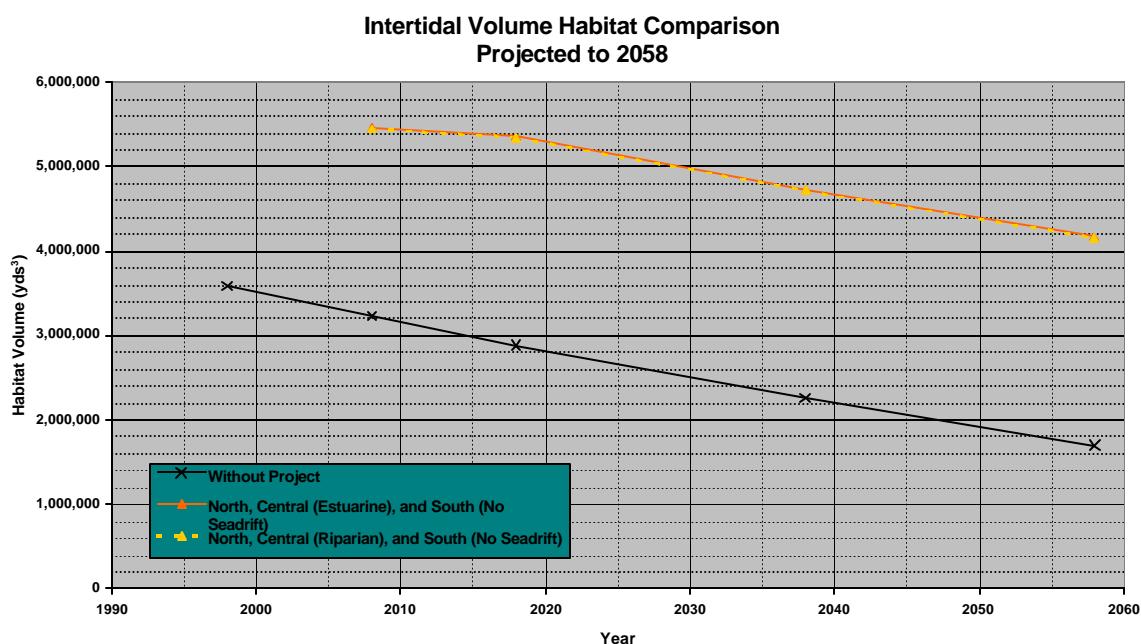


Figure 52 With Project Intertidal Habitat Volume Projection

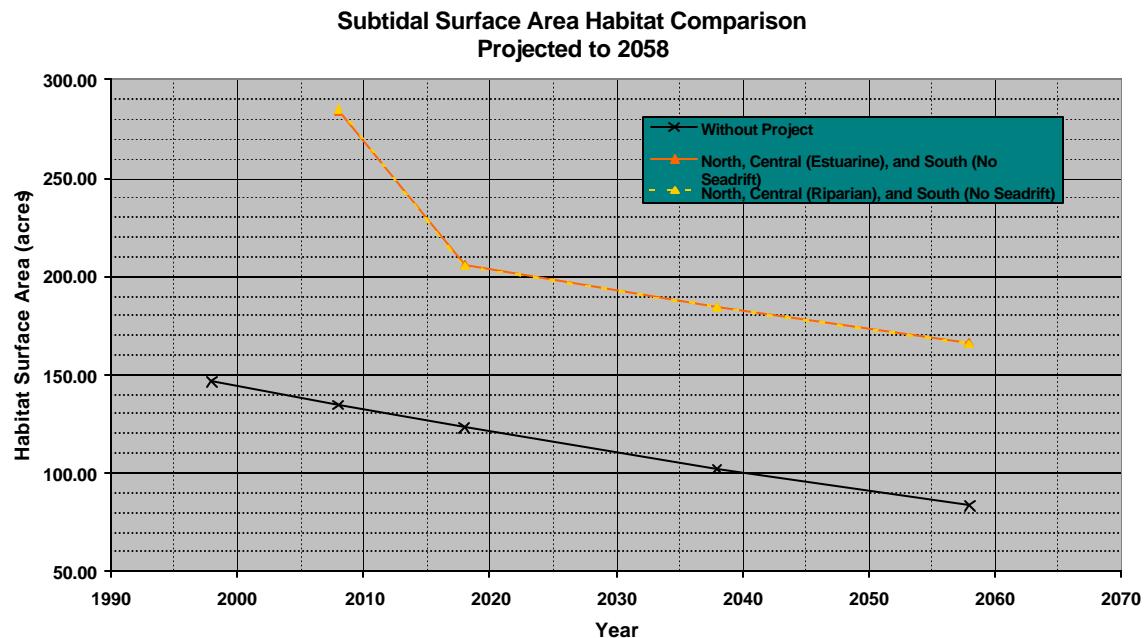


Figure 53 With Project Subtidal Habitat Surface Area Projection

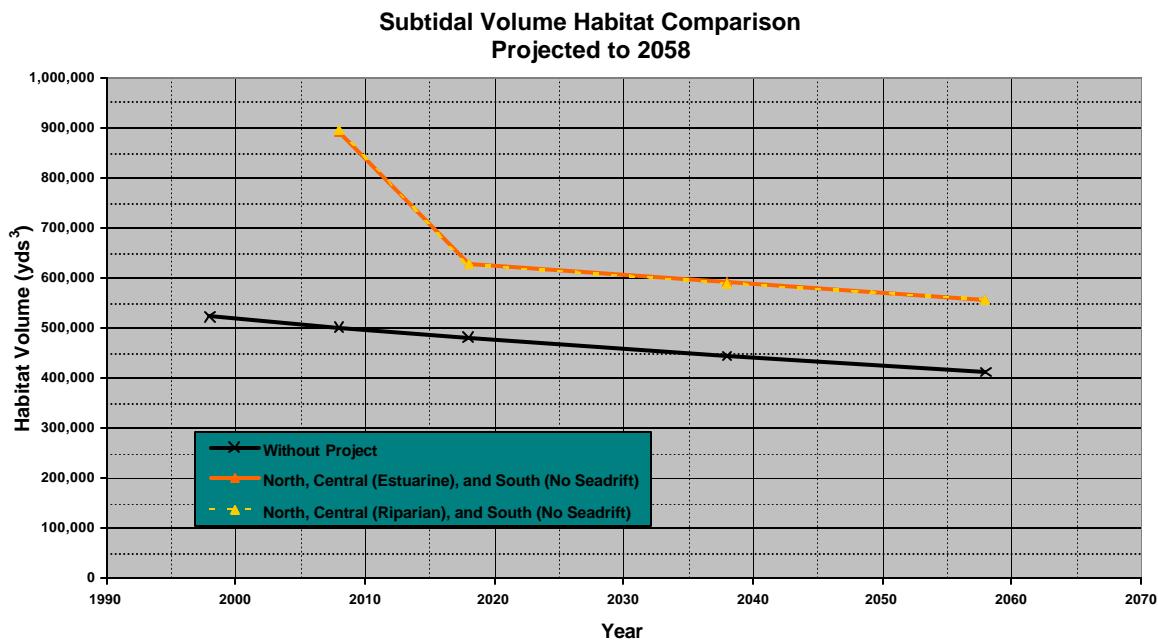


Figure 54 With Project Subtidal Habitat Volume Projection

With Project Diving Duck Habitat Surface Area

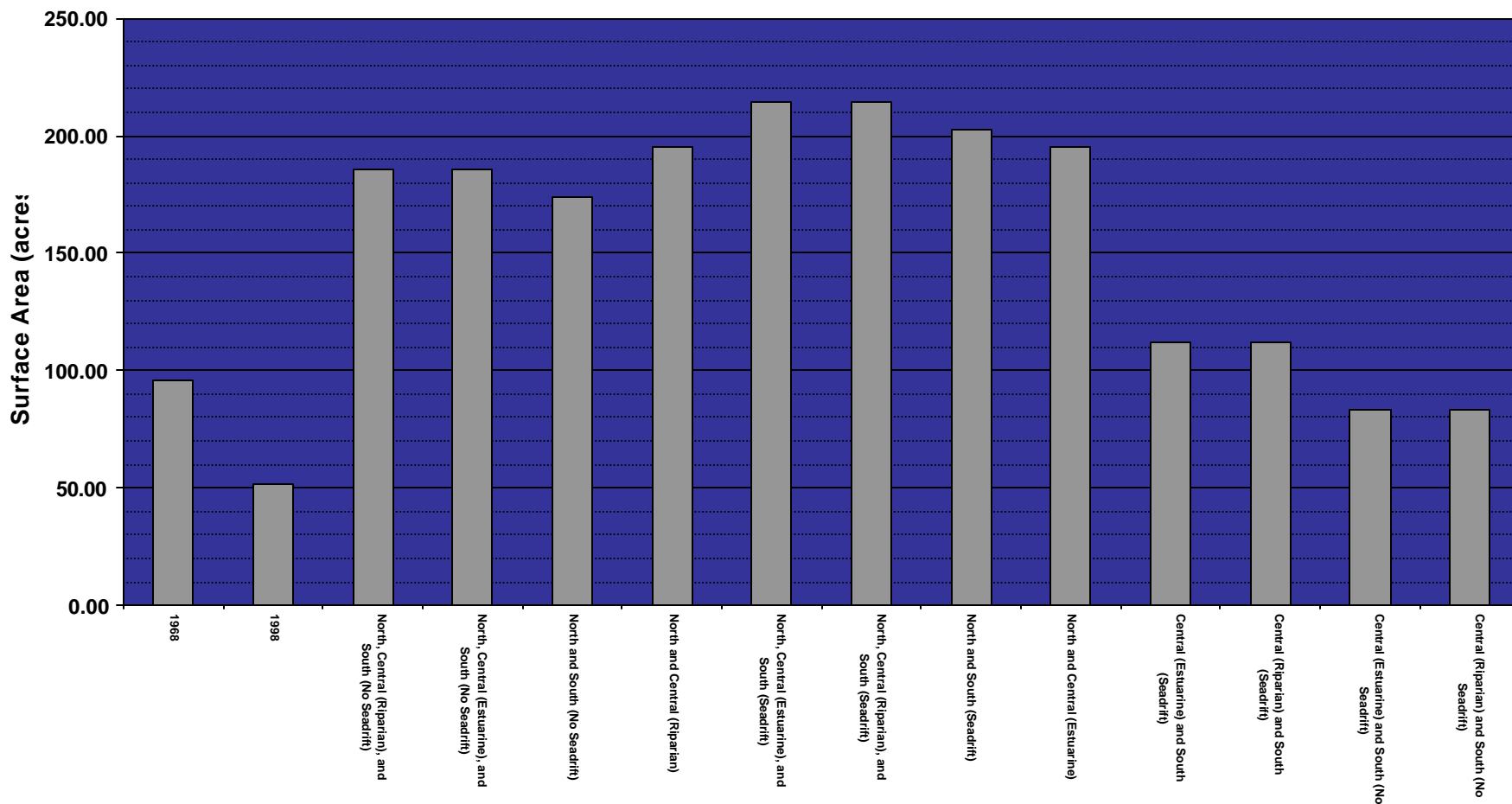


Figure 55 With Project Diving Duck Habitat

7 Numerical Modeling

Kamman Hydrology and Engineering, Inc., conducted a hydrodynamic assessment of Bolinas Lagoon with the use of Mike 21-HD, a numerical model used to analyze the existing conditions and several of the lagoon restoration alternatives. The model was used to simulate temporally and spatially variable tidal flows within the lagoon and tidal exchange between the lagoon and Bolinas Bay. The modeling was used to verify the hydraulic stability of the proposed channel configurations. The model was not used to predict future lagoon conditions.

The numerical model used to simulate tidal circulation in Bolinas Lagoon is a 2-dimensional finite difference model that operates on a uniform rectangular grid. The model is capable of simulating the following physical processes: bathymetric variations; water level variations; bottom friction; convective and cross momentum; momentum dispersion; Coriolis forces; wind shear stress; and barometric pressure gradients. The study conducted by Kamman Hydrology did not investigate changes in simulation results due to variations in wind and barometric pressure effects. They were assumed constant. The numerical model study also did not take into account freshwater inflow and storm impact. Since the model simulates hydrodynamic response over a fixed bed (bathymetry and inlet), it doesn't predict the extent or rate or inlet adjustment (Kamman 2001).

Tidal data provided by PWA was used to define water surface elevations along the open water boundary of the model. The lagoon bathymetry was used to define a no flow boundary condition at most points along the lagoon perimeter (Kamman 2001).

Chezy parameters that are constant throughout the simulation period (irrespective of flow depth) were used to characterize channel and marsh plain resistance. The resistance element values represent vegetation zones found at typical elevations within the lagoon (Kamman 2001).

Five restoration scenarios were evaluated: current conditions (no action); full construction (North, Central, and South alternatives); North and Central; North and South; and Central and South. North, Central, and South are defined as follows:

North: removal actions in the North Lagoon and along the Main Channel.

Central: Pine Gulch Creek Delta, Kent Island, and Bolinas Channel.

South: channel expansion within the South Lagoon, removal of the Dipsea Road fill, and the opening of Seadrift Lagoon to tidal action.

The results of the modeling indicate that in all scenarios, the predicted tide range is greatest near the inlet and decreases with hydraulic distance from the inlet. The greatest increase in tidal range (~ 0.5 m) occurs with the implementation of the North Lagoon component. Implementation of the Central restoration components accelerates tidal exchange between the inlet and the north lagoon.

Kamman Hydrology also found that the model results display a generally comparable increase in the upper and lower limit of the tidal range for all restoration alternatives. This is indicative of the following: increased inlet size is largely responsible for the overall increase in predicted lagoon tidal range; and the proposed Central components increase tidal exchange to the North Lagoon in the absence of the Main Channel excavation.

Kamman Hydrology also conducted a comparative analysis of tidal velocities in order to gain insight into lagoon circulation patterns and channel persistence (i.e., the ability of channel flows to sustain the proposed channel modifications). The study revealed that the west lagoon velocities are greatest under existing conditions and decrease only slightly for the restoration scenarios. Velocities in the west and east portions of Bolinas Channel display comparable changes for all the alternative scenarios that include a Central restoration component. Ebb and flood velocities in the western portion of Bolinas Channel increased by about 0.3 m/sec and 0.2 m/sec, respectively, which leads to an increase in tidal exchange in the western portion of Bolinas Channel (Kamman 2001).

Peak velocities of 1.2 m/sec predicted in the west portion of the Kent Island Channel are as much as 0.8 m/sec greater than those predicted for Bolinas Channel (west) and display strong flood dominance during spring tides (Kamman 2001).

Kamman Hydrology found that predicted velocities in the Main Channel do not vary as strongly between east and west locations. The velocity traces are in phase with the Kent Island traces, but have peak flood magnitudes that are approximately 0.2 m/sec lower than those predicted for Kent Island. The eastern Main Channel flood velocity peaks of 0.4 m/sec are comparable to those found in the East Channel during spring tides. However, Main Channel ebb velocity peaks are as much as 0.6 m/sec lower than those predicted for the East Channel. The Kamman Hydrology investigation also revealed that the 0.4 m/sec peak velocities in the eastern section of the Main Channel may not be sufficient to maintain the proposed channel geometry as these pulses only occur during maximum spring tides. Neap tide velocity maximums in the eastern Main Channel reach 0.2 m/sec diurnally, and are not likely to be sufficient to prevent channel sedimentation (Kamman 2001).

Similar to the Central Lagoon channels, Kamman Hydrology found that the East Channel displays flood-dominant velocities. Under 1998 conditions, maximum east channel flood flows reach 0.8 m/sec. After implementation of the restoration alternatives, East Channel velocities decrease with the largest decrease (to 0.4 m/sec) associated with the Full Construction scenario. Kamman Hydrology concluded that following restoration, the East Channel will continue to carry strong ebb flows from the eastern lagoon, while the

restored central components provide peak velocities during flood flows. The greatest East Channel velocities are associated with the North and South scenario.

Kamman Hydrology also investigated residual velocities within Bolinas Lagoon, which represent the cumulative total of predicted flow velocities over a mean tidal month simulation period. The study concluded that the potential for transport is strongest in the existing and proposed channels in the Central and North Lagoon, with the Central Lagoon channels providing a new component of tidal exchange to the North Lagoon. Based on the modeling results, the alternatives were found to be acceptable.

All figures associated with the numerical modeling study can be found in Appendix 22.

8 Conclusions

1. Bathymetric surveys show the loss of several channels within the lagoon.
2. The closure index analysis predicts that the lagoon will close in 35 years.
3. The lagoon had 7.6 million yds³ (156 acres) of upland habitat, 5.6 million yds³ (876 acres) of intertidal habitat, and 641,298 yds³ (213 acres) of subtidal habitat in 1968. The lagoon had 8.2 million yds³ (238 acres) of upland habitat, 3.6 million yds³ (849 acres) of intertidal habitat, and 523,318 yds³ (146 acres) of subtidal habitat in 1998. This change represents an increase of 0.6 million yds³ in the growth of upland habitat; a loss of 2 million yds³ of intertidal habitat; and a loss of 117,682 yds³ of subtidal habitat.
4. In the year 2058, predictions indicate that the lagoon will contain 8.8 million yds³ of upland habitat (316 acres), 1.7 million yds³ of intertidal habitat (823 acres), and 412,128 yds³ (83 acres) of subtidal habitat. Compared to the 1998 habitat levels, this represents a loss of 1.9 million yds³ of intertidal habitat and 111,190 yds³ of subtidal habitat. There is gain of 1.2 million yds³ of upland habitat.
5. The lagoon had 167.28 million ft³ (6.20 million yds³) of potential spring tidal prism and 140.75 million ft³ (5.21 million yds³) of effective spring tidal prism in 1968. The lagoon had 131.44 million ft³ (4.87 million yds³) of potential spring tidal prism and 86.03 million ft³ (3.19 million yds³) of effective spring tidal prism in 1998. The lagoon lost 35.84 million ft³ (1.33 million yds³) of potential spring tidal prism and 54.71 million ft³ (2.03 million yds³) of effective tidal prism between 1968 and 1998.
6. Calculations indicate that the lagoon will lose an additional 32.38 million ft³ (1.20 million yds³) of potential spring tidal prism by the year 2058, which represents a 25% loss of the 1998 potential tidal prism.
7. Calculations indicate that the lagoon will lose an additional 38.64 million ft³ (1.43 million yds³) of effective tidal prism by the year 2058, which represents a 45% loss of the 1998 effective tidal prism.

9 Bibliography and References

Bergquist, J.R. 1978. *Depositional history and fault-related studies, Bolinas Lagoon, California.* U.S. Department of the Interior, Geological Survey. Open file Report, 78-802

Bolinas Lagoon Management Plan Update 1996. Marin County Department of Parks, Open Space and Cultural Services.

Johnson, J.W. 1969. *Stabilization of the Bolinas Lagoon Inlet.* September, 1969.

Johnson, J.W. 1973. *Bolinas Lagoon Inlet, California.* University of California Hydraulic Engineering Laboratory Technical Report HEL 24-15. Berkeley, CA. February 1973.

Johnson, J.W. 1973. *Characteristics and Behavior of Pacific Coast Tidal Inlets.* Journal of the Waterways, Harbors and Coastal Engineering, American Society of Civil Engineers, Vol. 99, No. August, 1973.

O'Brien, M.P. 1931. *Estuary Tidal Prisms Related to Entrance Areas.* Civil Engineering, 738-739.

O'Brien, M.P. 1971. *Notes on Tidal Inlets on Sandy Shores.* Hydraulic Engineering Laboratory, College of Engineering, University of California, Berkeley. May, 1971.

O'Brien, M.P. 1980. *Comments on Tidal Entrances on Sandy Coasts.* Journal of Coastal Engineering. American Society of Civil Engineers. 1980.

Philip Williams and Associates, LTD. 1999. *Bolinas Lagoon Hydrographic Data Report Spring: April-May 1998 and Fall: October-November 1998.* Prepared for the U.S. Army Corps of Engineers - San Francisco District.

Philip Williams and Associates, LTD. 1999. *Bolinas Lagoon Supplemental Wave Analysis Report.* Prepared for the U.S. Army Corps of Engineers - San Francisco District.

Philip Williams and Associates, LTD. 1993. *Russian River Estuary Study: Hydrological Aspects of an Estuary Management Plan.* Prepared for the Department of Planning, Sonoma County, and the California State Coastal Conservancy.

Ritter, J.R. 1970. *Preliminary Studies of Sedimentation and Hydrology in Bolinas Lagoon, Marin County, California, May 1967-June 1968.*

Ritter, J.R. 1973. *Bolinas Lagoon, Marin County, California: Summary of Sedimentation and Hydrology, 1967-69.* U.S. Geological Survey, Water Resources Investigations 1973. August, 1973.

Rowntree, R.A. 1973. *Morphological changes in a California estuary: Sedimentation and Marsh Invasion at Bolinas Lagoon.* Ph.D. Dissertation, Department of Geography, Univ. California Berkeley.

Seabergh, W.C. and Kraus, N.C. 1997. *PC program for Coastal Inlet Stability Analysis Using Escoffier Method.* Coastal Engineering Technical Note, CETNIV-11, Coastal and Hydraulics Laboratory - U.S. Army Corps of Engineers.

U.S. Army Corps of Engineers. *Shore Protection Manual 1984 and 2001.* Coastal Engineering Research Center.

Vincent, C.L. and William D.C. 1981. *Geometry of Tidal Inlets: Empirical Equations.* Journal of the Waterway, Port, Coastal and Ocean Division. Proceedings of the American Society of Civil Engineers, Vol. 7, No. WW1, February 1981.

Wahrhaftig, C. and J. Bergquist. 1993. *Calculation of the Mean Tidal Prism of Bolinas Lagoon for 1978.* Memorandum to the members and consultants of the Bolinas Lagoon Technical Advisory Committee. U.S. Geological Survey. December 8, 1993.

Wilde, P. and Yancey, T. 1970. *Sediment Distribution and Its Relation to Circulation Patterns in Bolinas Bay, California.* Proceedings of the Twelfth Coastal Engineering Conference, Washington, D.C.

Williams, P.B. and Cuffe, C.K., 1994. *The Management Implications of the Potential for Closure of Bolinas Lagoon.* Shore and Beach Vol. 62, No. 4, October 1994 - Journal of The American Shore and Beach Preservation Society.

BOLINAS LAGOON ECOSYSTEM RESTORATION PROJECT

APPENDICES TO THE WATER RESOURCES APPENDIX

Lisa Romanoski
John Winkelman
US Army Corps of Engineers
SAN FRANCISCO DISTRICT

APPENDIX 1

SPRING LAGOON TIDAL CONDITION (1998)

Calculation of Effective Tidal Prism From Collected Data

4/24 Bolinas Bay Range 6.38 ft Maximum Water Elevation					4/25 Bolinas Bay Range 7.07 ft Maximum Water Elevation				
	elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³		elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³
south	2.63	116.11	0.47	55.04	south	2.62	115.67	0.47	54.71
north	2.5	110.32	0.53	58.03	north	2.57	113.44	0.53	59.78
total					total				
113.06					114.49				
Minimum Water Elevation					Minimum Water Elevation				
	elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³		elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³
south	-0.8	19.56	0.53	10.33	south	-0.82	19.3	0.53	10.25
north	-0.08	28.85	0.47	13.62	north	-0.38	24.98	0.47	11.72
total					21.96				
Tidal Prism =					Tidal Prism =				
89.12					92.53				

11/2 Bolinas Bay Range 6.36 ft Maximum Water Elevation					11/8 Bolinas Bay Range 6.55 ft Maximum Water Elevation				
	elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³		elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³
south	2.84	125.48	0.47	59.23	south	2.74	121.02	0.47	57.36
north	2.5	110.32	0.53	58.25	north	2.37	104.73	0.53	55.09
total					112.45				
Minimum Water Elevation					Minimum Water Elevation				
	elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³		elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³
south	-0.77	19.95	0.54	10.71	south	-1.31	14.99	0.55	8.20
north	-1.1	16.34	0.46	7.57	north	-1.64	12.87	0.45	5.83
total					14.03				
Tidal Prism =					Tidal Prism =				
99.20					98.42				

Calculation of Potential Tidal Prism (Lagoon Range = Ocean Range)

*Uniform Water Surface Elevation

4/24		
3.39 to -2.99		
stage	elevation ft	volume million ft ³
high	3.39	151.07
low	-2.99	8
t.p.	143.07	

4/25		
3.54 to -3.53		
stage	elevation ft	volume million ft ³
high	3.54	158.2
low	-3.53	6.93
t.p.	151.27	

11/2		
3.54 to -2.82		
stage	elevation ft	volume million ft ³
high	3.54	158.2
low	-2.82	8.52
t.p.	149.68	

11/8		
3.24 to -3.31		
stage	elevation ft	volume million ft ³
high	3.24	143.9
low	-3.31	7.36
t.p.	136.54	

Typical Spring Tide Range

Average 3.15 to -3.45

stage	elevation ft	volume million ft ³
high	3.15	139.39
low	-3.45	7.09
t.p.	132.3	

Effective/Potential Tidal Prism Ratio

date	potential	effective	ratio
4/24	143.07	89.12	0.62
4/25	151.27	92.53	0.61
11/2	149.68	99.20	0.66
11/8	136.54	98.42	0.72
	average	0.65	

Typical Spring Tide Effective Tidal Prism Determination

Potential tidal prism for spring tide = 132.3
Ratio of effective to Potential = 0.65

Typical Spring Tidal Prism **86.60**

Expected Maximum Elevation In Lagoon For Spring Tides

Date	Lagoon	Ocean	Ratio
4/24	2.7	3.39	0.80
4/25	2.79	3.54	0.79
11/2	2.78	3.54	0.78
11/3	3.08	3.82	0.81
11/5	3.16	3.81	0.83
11/8	2.69	3.24	0.83
	average	0.81	

Typical Spring Tide (Ocean High) = 3.15
Ratio of Ocean to Lagoon Tide Height = 0.81

Maximum Elevation In Lagoon At Individual Locations = **2.54 ft (NGVD)**

Expected Minimum Elevation In Lagoon For Spring Tides

Date	Lagoon	Ocean	Ratio
4/24	-0.78	-2.99	0.26
4/25	-0.97	-3.53	0.27
11/2	-0.96	-2.82	0.34
11/3	-1.21	-3.5	0.35
11/5	-1.55	-4.2	0.37
11/8	-1.55	-3.31	0.47
	average	0.34	

Typical Spring Tide (Ocean Low) = -3.45
Ratio of Ocean to Lagoon Tide Height = 0.34

Minimum Elevation In Lagoon At Individual Locations = -1.18 ft (NGVD)

Expected Maximum Range In Lagoon For Spring Tides

Date	Lagoon	Ocean	Ratio
4/24	3.28	6.38	0.51
4/25	3.76	7.07	0.53
11/2	3.74	6.36	0.59
11/3	4.28	7.32	0.58
11/5	4.7	8.01	0.59
11/8	4.23	6.55	0.65
	average	0.58	

Typical Spring Tide (Ocean Range) = 6.6
Ratio of Ocean to Lagoon Tide Range = 0.58

Maximum Range In Lagoon At Individual Locations = 3.80 ft (NGVD)

Tidal Prism Calculation From Inlet Survey Flow Volume

Calculation of Tidal Prism Flow Data

04/28/98 Inlet Survey data

time	tide height ft (NGVD)	flow ft ³ /s	volume ft ³
9:30	-1.2393	0	
9:40	-1.2718	247.22	74,166
9:50	-1.1852	494.44	222,498
10:00	-1.196	741.66	370,830
10:10	-1.0444	120	258,498
10:20	-0.817	367.22	146,166
10:30	-0.7304	614.44	294,498
10:40	-0.5247	861.66	442,830
10:50	-0.5139	1108.88	591,162
11:00	-0.3298	2225	1,000,164
11:10	-0.1349	2412.44	1,391,232
11:20	0.1142	2599.88	1,503,696
11:30	0.3091	2787.32	1,616,160
11:40	0.4498	2974.76	1,728,624
11:50	0.6339	3162.2	1,841,088
12:00	0.7747	3349.64	1,953,552
12:10	0.9155	3537.08	2,066,016
12:20	1.0021	3724.52	2,178,480
12:30	1.1428	3911.96	2,290,944
12:40	1.2078	4099.4	2,403,408
12:50	1.3486	4286.84	2,515,872
13:00	1.4569	4474.28	2,628,336
13:10	1.5543	4661.72	2,740,800
13:20	1.6626	4849.16	2,853,264
13:30	1.7276	5036.6	2,965,728
13:40	1.7817	5224	3,078,180
13:50	1.8034	4179.2	2,820,960
14:00	1.8575	3134.4	2,194,080
14:10	1.8467	2089.6	1,567,200
14:20	1.8575	1044.8	940,320
14:30	1.8683	0	313,440
		total flow	46,992,192

11/13/98 Inlet Survey Data

time	tide height ft (NGVD)	flow ft ³ /s	volume ft ³
8:10	2.4	0	
8:20	2.2862	361	108,300
8:30	2.2537	722	324,900
8:40	2.2754	1083	541,500
8:50	2.1021	1444	758,100
9:00	2.1021	1805	974,700
9:10	1.9505	2166	1,191,300
9:20	1.8856	2527	1,407,900
9:30	1.734	2888	1,624,500
9:40	1.6582	3249	1,841,100
9:50	1.6365	3610	2,057,700
10:00	1.604	3971	2,274,300
10:10	1.5174	3915.5	2,365,950
10:20	1.2467	3860	2,332,650
10:30	1.106	3804.5	2,299,350
10:40	1.0735	3749	2,266,050
10:50	0.9219	3693.5	2,232,750
11:00	0.8461	3638	2,199,450
11:10	0.662	3582.5	2,166,150
11:20	0.5321	3527	2,132,850
11:30	0.5645	3471.5	2,099,550
11:40	0.3696	3416	2,066,250
11:50	0.3913	3360.5	2,032,950
12:00	0.1747	3305	1,999,650
12:10	0.1856	3188.67	1,948,101
12:20	0.1098	3072.34	1,878,303
12:30	-0.0202	2956.01	1,808,505
12:40	-0.0743	2839.68	1,738,707
12:50	-0.1826	2723.35	1,668,909
13:00	-0.2692	2607.02	1,599,111
13:10	-0.3883	2490.69	1,529,313
13:20	-0.3667	2374.36	1,459,515
13:30	-0.4316	2258	1,389,708
13:40	-0.3775	1806.4	1,219,320
13:50	-0.4966	1354.8	948,360
14:00	-0.5616	903.2	677,400
14:10	-0.5507	451.6	406,440
14:20	-0.6807	0	135,480
		total flow	57,705,072

Inlet Survey Day Tidal Prism Calculation

4/28 Bolinas Bay Range Maximum Water Elevation					11/13 Bolinas Bay Range Maximum Water Elevation				
	elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³		elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³
south	1.82	83.1	0.49	40.72	south	1.96	87.98	0.49	42.85
north	1.53	73	0.51	37.23	north	1.73	79.96	0.51	41.02
total					total				
Minimum Water Elevation					Minimum Water Elevation				
	elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³		elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³
south	-0.74	20.33	0.53	10.69	south	-0.79	19.69	0.54	10.57
north	0.0136	29.7	0.47	14.08	north	-1.07	16.53	0.46	7.65
total					total				
Tidal Prism =					Tidal Prism =				
53.18					65.64				

*Note: The East Gage was not operational at the time of the survey on 04/28 leading to possible error in the lagoon's average elevation calculations for that day.

Comparison

4/28

Description	million ft ³
Measured Inlet Survey Tidal Prism	46.99
Calculated Volume/Depth Chart Tidal Prism	53.18
difference	6.19

11/13

Description	million ft ³
Measured Inlet Survey Tidal Prism	57.71
Calculated Volume/Depth Chart Tidal Prism	65.64
difference	7.93

APPENDIX 2

NEAP LAGOON TIDAL CONDITION (1998)

Calculation of Effective Tidal Prism From Collected Data

4/18 Bolinas Bay Range Maximum Water Elevation					4/22 Bolinas Bay Range Maximum Water Elevation								
	elevation ft	volume million ft ³	% for avg. depth	T.P. Sect. million ft ³		elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³				
south	1.52	72.66	0.49	35.75	south	1.86	84.5	0.49	41.24				
north	1.66	77.53	0.51	39.46	north	1.7	78.92	0.51	40.41				
	total		75.21			total		81.64					
Minimum Water Elevation					Minimum Water Elevation								
	elevation ft	volume million ft ³	% for avg. depth	T.P. Sect. million ft ³		elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³				
south	-2.08	10.78	0.55	5.94	south	-1.03	16.79	0.54	9.00				
north	-1.32	14.93	0.45	6.70	north	-0.73	20.46	0.46	9.49				
	total		12.64			total		18.49					
Tidal Prism = 62.57					Tidal Prism = 63.15								
10/27 Bolinas Bay Range Maximum Water Elevation					10/30 Bolinas Bay Range Maximum Water Elevation								
	elevation ft	volume million ft ³	% for avg. depth	T.P. Sect. million ft ³		elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³				
south	2.03	90.62	0.49	44.13	south	1.72	79.62	0.49	39.25				
north	1.67	77.88	0.51	39.98	north	1.33	66.04	0.51	33.48				
	total		84.11			total		72.73					
Minimum Water Elevation					Minimum Water Elevation								
	elevation ft	volume million ft ³	% for avg. depth	T.P. Sect. million ft ³		elevation ft	T.P. Lag. million ft ³	% for avg. depth	T.P. Sect. million ft ³				
south	-1.35	14.73	0.55	8.07	south	-1.19	15.76	0.55	8.59				
north	-1.78	11.97	0.45	5.41	north	-1.56	13.39	0.46	6.09				
	total		13.48			total		14.68					
Tidal Prism = 70.63					Tidal Prism = 58.05								

Calculation of Potential Tidal Prism (Lagoon Range = Ocean Range)

*Uniform Water Surface Elevation

4/18
2.08 to -2.23

stage	elevation ft	volume million ft ³
high	2.08	92.69
low	-2.33	10.02
t.p.	82.67	

4/22
2.42 to -2.26

stage	elevation ft	volume million ft ³
high	2.42	106.81
low	-2.26	10.24
t.p.	96.57	

10/27
2.22 to -2.16

stage	elevation ft	volume million ft ³
high	2.22	98.5
low	-2.16	10.54
t.p.	87.96	

10/30
2.1 to -2.31

stage	elevation ft	volume million ft ³
high	2.1	93.52
low	-2.31	10.08
t.p.	83.44	

Typical Neap Tide Range
Average 2.25 to -2.05

stage	elevation ft	volume million ft ³
high	2.25	99.75
low	-2.05	10.88
t.p.	88.87	

Effective/Potential Tidal Prism Ratio

date	potential	effective	ratio
4/18	82.67	62.57	0.76
4/22	96.57	63.15	0.65
10/27	87.96	70.63	0.80
10/30	83.44	58.05	0.70
	average		0.73

Typical Neap Tide Effective Tidal Prism Determination

Potential tidal prism for spring tide =	88.87
Ratio of effective to potential =	0.73
Typical Spring Tidal Prism	64.64

Expected Maximum Elevation In Lagoon For Neap Tides

Date	Lagoon	Ocean	Ratio
4/18	1.72	2.08	0.83
4/22	1.87	2.42	0.77
10/27	1.96	2.22	0.88
10/30	1.64	2.1	0.78
	average	0.82	

Typical Neap Tide (Ocean High) = 2.25
Ratio of Ocean to Lagoon Tide Height = 0.82

For 4/18 and 4/22 the south gage was excluded from the calculations due to the bottoming out at low tide. This would have skewed the calculations. The effect was found to be negligible.

Maximum Elevation In Lagoon At Individual Locations = 1.84 ft (NGVD)

Expected Minimum Elevation In Lagoon For Spring Tides

Date	Lagoon	Ocean	Ratio
4/18	-1.83	-2.23	0.82
4/22	-1.22	-2.26	0.54
10/27	-1.50	-2.16	0.69
10/30	-1.38	-2.31	0.60
	average	0.66	

Typical Neap Tide (Ocean Low) = -2.05
Ratio of Ocean to Lagoon Tide Height = 0.66

For 4/18 and 4/22 the south gage was excluded from the calculations due to the bottoming out at low tide. This would have skewed the calculations. The effect was found to be negligible.

Minimum Elevation In Lagoon At Individual Locations = -1.36 ft (NGVD)

Expected Maximum Range In Lagoon For Spring Tides

Date	Lagoon	Ocean	Ratio
4/18	3.55	4.31	0.82
4/22	3.09	4.68	0.66
10/27	3.46	4.38	0.79
10/30	3.02	4.41	0.68
	average	0.74	

Typical Neap Tide (Ocean Range) = 4.3
Ratio of Ocean to Lagoon Tide Height = 0.74

For 4/18 and 4/22 the south gage was excluded from the calculations due to the bottoming out at low tide. This would have skewed the calculations. The effect was found to be negligible.

Maximum Range In Lagoon At Individual Locations = 3.18 ft (NGVD)

APPENDIX 3

1968 TIDAL RECORD

Spring Tides

Date	Time	Presidio	Presido	South	North	Average
	hours	ft-MLLW	ft-NGVD	ft-NGVD	ft-NGVD	ft-NGVD
8/2/67	18:00	5.23	2.38	2.22	1.92	2.07
8/2/67	18:30	5.53	2.68	2.43	2.14	2.28
8/2/67	19:00	5.83	2.98	2.64	2.36	2.50
8/2/67	19:30	5.98	3.13	2.85	2.57	2.71
8/2/67	20:00	6.13	3.28	3.06	2.79	2.93
8/2/67	20:30	6.13	3.53	3.27	3.01	3.14
8/2/67	21:00	6.13	3.28	2.97	2.72	2.84
8/2/67	21:30	5.78	2.93	2.67	2.42	2.55
8/2/67	22:00	5.43	2.58	2.37	2.13	2.25
8/2/67	22:30	4.83	1.98	2.07	1.83	1.95
8/2/67	23:00	4.23	1.38	1.77	1.54	1.65
8/2/67	23:30	3.43	0.58	1.47	1.24	1.36
8/3/67	0:00	2.63	-0.22	1.17	0.95	1.06
8/3/67	0:30	1.98	-0.87	0.87	0.65	0.76
8/3/67	1:00	1.33	-1.52	0.57	0.36	0.46
8/3/67	1:30	0.83	-2.02	0.27	0.06	0.17
8/3/67	2:00	0.33	-2.52	-0.03	-0.23	-0.13
8/3/67	2:30	0.03	-2.82	-0.33	-0.53	-0.43
8/3/67	3:00	-0.27	-3.12	-0.63	-0.82	-0.73
8/3/67	3:30	-0.27	-3.37	-0.93	-1.12	-1.03
8/3/67	4:00	-0.27	-3.12	-1.23	-1.42	-1.32
8/3/67	4:30	-0.07	-2.92	-1.53	-1.71	-1.62
8/3/67	5:00	0.13	-2.72	-1.83	-2.01	-1.92
8/3/67	5:30	0.53	-2.32	-2.13	-2.3	-2.22
8/3/67	6:00	0.93	-1.92	-1.73	-2.04	-1.89
8/3/67	6:30			-1.33	-1.78	-1.56
8/3/67	7:00			-0.93	-1.52	-1.23
8/3/67	7:30			-0.53	-1.26	-0.90
8/3/67	8:00			-0.13	-1	-0.57
8/3/67	8:30			0.27	-0.74	-0.24

*Bolinas Lagoon Ecosystem Restoration Project
Technical Appendices: Engineering Appendix*

Date	Time	Presidio	Presido	South	North	Average
	hours	ft-MLLW	ft-NGVD	ft-NGVD	ft-NGVD	ft-NGVD
8/7/67	21:00			1.65	0.83	1.24
8/7/67	21:30			2.03	1.26	1.65
8/7/67	22:00	5.13	2.28	2.41	1.70	2.06
8/7/67	22:30	5.53	2.68	2.79	2.14	2.46
8/7/67	23:00	5.93	3.08	3.17	2.58	2.87
8/7/67	23:30	6.18	3.33	3.55	3.01	3.28
8/8/67	0:00	6.43	3.58	3.40	3.23	3.31
8/8/67	0:30	6.28	3.43	3.24	3.45	3.35
8/8/67	1:00	6.13	3.28	2.93	3.16	3.05
8/8/67	1:30	5.73	2.88	2.63	2.86	2.75
8/8/67	2:00	5.33	2.48	2.32	2.57	2.44
8/8/67	2:30	4.53	1.68	2.01	2.28	2.14
8/8/67	3:00	3.73	0.88	1.70	1.99	1.84
8/8/67	3:30	2.83	-0.02	1.39	1.69	1.54
8/8/67	4:00	1.93	-0.92	1.09	1.40	1.24
8/8/67	4:30	1.33	-1.52	0.78	1.11	0.94
8/8/67	5:00	0.73	-2.12	0.47	0.81	0.64
8/8/67	5:30	0.28	-2.57	0.16	0.52	0.34
8/8/67	6:00	-0.17	-3.02	-0.14	0.23	0.04
8/8/67	6:30	-0.27	-3.12	-0.45	-0.07	-0.26
8/8/67	7:00	-0.37	-3.22	-0.76	-0.36	-0.56
8/8/67	7:30	-0.12	-2.97	-1.07	-0.65	-0.86
8/8/67	8:00	0.13	-2.72	-1.38	-0.94	-1.16
8/8/67	8:30	0.58	-2.27	-1.01	-1.24	-1.12
8/8/67	9:00	1.03	-1.82	-0.65	-1.53	-1.09
8/8/67	9:30			-0.29	-0.95	-0.62
8/8/67	10:00			0.08	-0.37	-0.14
8/8/67	10:30			0.44	0.22	0.33
8/8/67	11:00			0.8	0.80	0.80
8/8/67	11:30			1.16	1.38	1.27

*Bolinas Lagoon Ecosystem Restoration Project
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Date	Time	Presidio	Presidio	South	North	Average
	hours	ft-MLLW	ft-NGVD	ft-NGVD	ft-NGVD	ft-NGVD
9/1/67	18:30			2.04	1.65	1.84
9/1/67	19:00	5.63	2.78	2.30	1.96	2.13
9/1/67	19:30	5.88	3.03	2.56	2.27	2.42
9/1/67	20:00	6.13	3.28	2.83	2.58	2.70
9/1/67	20:30	6.13	3.51	3.09	2.89	2.99
9/1/67	21:00	6.13	3.28	3.35	3.20	3.28
9/1/67	21:30	5.93	3.08	3.05	2.91	2.98
9/1/67	22:00	5.73	2.88	2.76	2.63	2.69
9/1/67	22:30	5.18	2.33	2.46	2.34	2.40
9/1/67	23:00	4.63	1.78	2.16	2.05	2.11
9/1/67	23:30	3.78	0.93	1.86	1.76	1.81
9/2/67	0:00	2.93	0.08	1.57	1.48	1.52
9/2/67	0:30	2.18	-0.67	1.27	1.19	1.23
9/2/67	1:00	1.43	-1.42	0.97	0.90	0.94
9/2/67	1:30	0.83	-2.02	0.67	0.62	0.64
9/2/67	2:00	0.23	-2.62	0.38	0.33	0.35
9/2/67	2:30	-0.17	-3.02	0.08	0.04	0.06
9/2/67	3:00	-0.57	-3.42	-0.22	-0.25	-0.23
9/2/67	3:30	-0.62	-3.47	-0.52	-0.53	-0.53
9/2/67	4:00	-0.67	-3.52	-0.81	-0.82	-0.82
9/2/67	4:30	-0.42	-3.27	-1.11	-1.11	-1.11
9/2/67	5:00	-0.17	-3.02	-1.41	-1.40	-1.40
9/2/67	5:30	0.23	-2.62	-1.71	-1.68	-1.69
9/2/67	6:00	0.63	-2.22	-1.43	-1.97	-1.70
9/2/67	6:30			-1.01	-1.55	-1.28
9/2/67	7:00			-0.58	-1.14	-0.86
9/2/67	7:30			-0.16	-0.72	-0.44
9/2/67	8:00			0.05	-0.30	-0.13
9/2/67	8:30			0.47	0.11	0.29

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Date	Time	Presidio	Presidio	South	North	Average
	hours	ft-MLLW	ft-NGVD	ft-NGVD	ft-NGVD	ft-NGVD
9/4/67	20:30			1.72	1.00	1.36
9/4/67	21:00	4.43	1.58	2.00	1.35	1.67
9/4/67	21:30	4.83	1.98	2.28	1.70	1.99
9/4/67	22:00	5.23	2.38	2.56	2.05	2.30
9/4/67	2:30	5.58	2.73	2.83	2.40	2.62
9/4/67	23:00	5.93	3.08	3.11	2.75	2.93
9/4/67	23:30	5.78	2.93	3.10	3.10	3.10
9/5/67	0:00	5.63	2.78	2.81	3.14	2.98
9/5/67	0:30	5.08	2.23	2.52	2.87	2.70
9/5/67	1:00	4.53	1.68	2.22	2.60	2.41
9/5/67	1:30	3.83	0.98	1.93	2.33	2.13
9/5/67	2:00	3.13	0.28	1.64	2.06	1.85
9/5/67	2:30	2.43	-0.42	1.34	1.79	1.57
9/5/67	3:00	1.73	-1.12	1.05	1.52	1.29
9/5/67	3:30	1.18	-1.67	0.75	1.25	1.00
9/5/67	4:00	0.63	-2.22	0.46	0.98	0.72
9/5/67	4:30	0.13	-2.72	0.17	0.71	0.44
9/5/67	5:00	-0.37	-3.22	-0.13	0.44	0.16
9/5/67	5:30	-0.37	-3.67	-0.42	0.17	-0.12
9/5/67	6:00	-0.37	-3.22	-0.71	-0.10	-0.41
9/5/67	6:30	0.03	-2.82	-1.01	-0.37	-0.69
9/5/67	7:00	0.43	-2.42	-1.30	-0.64	-0.97
9/5/67	7:30	1.08	-1.77	-0.89	-0.91	-0.90
9/5/67	8:00	1.73	-1.12	-0.48	-1.18	-0.83
9/5/67	8:30			-0.06	-0.86	-0.46
9/5/67	9:00			0.35	-0.54	-0.10
9/5/67	9:30			0.76	-0.22	0.27
9/5/67	10:00			1.18	0.1	0.64

Neap Tides

Date	Time	Presidio	Presidio	South	North	Average
	hours	ft-MLLW	ft-NGVD	ft-NGVD	ft-NGVD	ft-NGVD
7/26/67	0:00	4.33	1.48	1.40	1.05	1.23
7/26/67	0:30	4.53	1.68	1.54	1.23	1.39
7/26/67	1:00	4.73	1.88	1.68	1.41	1.55
7/26/67	1:30	4.93	2.08	1.82	1.59	1.71
7/26/67	2:00	5.13	2.28	1.96	1.77	1.87
7/26/67	2:30	4.98	2.13	2.10	1.95	2.03
7/26/67	3:00	4.83	1.98	1.84	1.71	1.77
7/26/67	3:30	4.38	1.53	1.58	1.47	1.52
7/26/67	4:00	3.93	1.08	1.32	1.23	1.27
7/26/67	4:30	3.38	0.53	1.06	0.99	1.02
7/26/67	5:00	2.83	-0.02	0.80	0.75	0.77
7/26/67	5:30	2.23	-0.62	0.54	0.51	0.52
7/26/67	6:00	1.63	-1.22	0.28	0.27	0.27
7/26/67	6:30	1.23	-1.62	0.01	0.03	0.02
7/26/67	7:00	0.83	-2.02	-0.25	-0.21	-0.23
7/26/67	7:30	0.63	-2.22	-0.51	-0.45	-0.48
7/26/67	8:00	0.43	-2.42	-0.77	-0.69	-0.73
7/26/67	8:30	0.58	-2.27	-1.03	-0.93	-0.98
7/26/67	9:00	0.73	-2.12	-1.29	-1.17	-1.23
7/26/67	9:30	1.03	-1.82	-1.55	-1.41	-1.48
7/26/67	10:00	1.33	-1.52	-1.19	-1.65	-1.42
7/26/67	10:30			-0.83	-1.15	-0.99
7/26/67	11:00			-0.47	-0.65	-0.56
7/26/67	11:30			-0.11	-0.15	-0.13
7/26/67	12:00			0.25	-0.35	-0.05

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Date	Time	Presidio	Presidio	South	North	Average
	hours	ft-MLLW	ft-NGVD	ft-NGVD	ft-NGVD	ft-NGVD
8/22/67	23:00	4.53	1.68	1.50	0.85	1.18
8/22/67	23:30	4.78	1.93	1.67	1.15	1.41
8/23/67	0:00	5.03	2.18	1.84	1.45	1.64
8/23/67	0:30	5.13	2.28	2.01	1.75	1.88
8/23/67	1:00	5.23	2.38	2.18	2.04	2.11
8/23/67	1:30	5.08	2.23	2.35	2.34	2.35
8/23/67	2:00	4.93	2.08	2.11	2.12	2.11
8/23/67	2:30	4.58	1.73	1.86	1.90	1.88
8/23/67	3:00	4.23	1.38	1.62	1.68	1.65
8/23/67	3:30	3.58	0.73	1.38	1.46	1.42
8/23/67	4:00	2.93	0.08	1.14	1.24	1.19
8/23/67	4:30	2.43	-0.42	0.89	1.02	0.95
8/23/67	5:00	1.93	-0.92	0.65	0.80	0.72
8/23/67	5:30	1.53	-1.32	0.41	0.57	0.49
8/23/67	6:00	1.13	-1.72	0.16	0.35	0.26
8/23/67	6:30	1.03	-1.82	-0.08	0.13	0.03
8/23/67	7:00	0.93	-1.92	-0.32	-0.09	-0.20
8/23/67	7:30	1.08	-1.77	-0.56	-0.31	-0.44
8/23/67	8:00	1.23	-1.62	-0.81	-0.53	-0.67
8/23/67	8:30	1.53	-1.32	-1.05	-0.75	-0.90
8/23/67	9:00	1.83	-1.02	-0.73	-0.97	-0.85
8/23/67	9:30			-0.41	-0.75	-0.58
8/23/67	10:00			-0.09	-0.53	-0.31
8/23/67	10:30			0.23	-0.31	-0.04
8/23/67	11:00			0.55	-0.09	0.23
8/23/67	11:30			0.87	0.13	0.50

*Bolinas Lagoon Ecosystem Restoration Project
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Date	Time	Presidio	Presidio	South	North	Average
	hours	ft-MLLW	ft-NGVD	ft-NGVD	ft-NGVD	ft-NGVD
9/7/67	0:00	5.03	2.18	1.45	0.75	1.10
9/7/67	0:30	5.23	2.38	1.64	1.00	1.32
9/7/67	1:00	5.43	2.58	1.82	1.25	1.54
9/7/67	1:30	5.28	2.43	2.01	1.50	1.75
9/7/67	2:00	5.13	2.28	2.19	1.75	1.97
9/7/67	2:30	4.73	1.88	2.38	2.00	2.19
9/7/67	3:00	4.33	1.48	2.10	2.25	2.17
9/7/67	3:30	3.63	0.78	1.82	2.01	1.91
9/7/67	4:00	2.93	0.08	1.53	1.76	1.65
9/7/67	4:30	2.23	-0.62	1.25	1.52	1.39
9/7/67	5:00	1.53	-1.32	0.97	1.27	1.12
9/7/67	5:30	1.13	-1.72	0.69	1.03	0.86
9/7/67	6:00	0.73	-2.12	0.41	0.79	0.60
9/7/67	6:30	0.73	-2.20	0.13	0.54	0.34
9/7/67	7:00	0.73	-2.12	-0.16	0.30	0.07
9/7/67	7:30	0.98	-1.87	-0.44	0.06	-0.19
9/7/67	8:00	1.23	-1.62	-0.72	-0.19	-0.45
9/7/67	8:30	1.78	-1.07	-1.00	-0.43	-0.72
9/7/67	9:00	2.33	-0.52	-0.68	-0.68	-0.68
9/7/67	9:30			-0.36	-0.92	-0.64
9/7/67	10:00			-0.04	-0.71	-0.37
9/7/67	10:30			0.28	-0.50	-0.11
9/7/67	11:00			0.60	-0.28	0.16
9/7/67	11:30			0.92	-0.07	0.43

APPENDIX 4

SPRING LAGOON TIDAL CONDITION (1968)

Typical Spring Tide Lagoon Condition Calculations 1968

Calculation of Effective Tidal Prism From Collected Data

8/2 6.4 ft	
Max. Elevation	
elevation ft	T.P. Lag. million ft ³
3.14	177.53
Min. Elevation	
elevation ft	T.P. Lag. million ft ³
-2.22	14.45
T.P. = 163.08	

8/7 6.4 ft	
Max. Elevation	
elevation ft	T.P. Lag. million ft ³
3.35	187.92
Min. Elevation	
elevation ft	T.P. Lag. million ft ³
-1.16	24.25
T.P. = 163.67	

9/1 6.4 ft	
Max. Elevation	
elevation ft	T.P. Lag. million ft ³
3.28	184.45
Min. Elevation	
elevation ft	T.P. Lag. million ft ³
-1.70	18.32
T.P. = 166.13	

9/4 6.4 ft	
Max. Elevation	
elevation ft	T.P. Lag. million ft ³
3.10	175.51
Min. Elevation	
elevation ft	T.P. Lag. million ft ³
-0.97	26.68
T.P. = 148.83	

Calculation of Potential Tidal Prism (Lagoon Range = Ocean Range)

*Uniform Water Surface Elevation

stage	elevation ft	volume million ft ³
high	3.53	196.86
low	-3.37	8.76
t.p.	188.1	

stage	elevation ft	volume million ft ³
high	3.58	199.34
low	-3.22	9.21
t.p.	190.13	

stage	elevation ft	volume million ft ³
high	3.51	193.83
low	-3.52	-8.33
t.p.	202.16	

stage	elevation ft	volume million ft ³
high	3.08	174.53
low	-3.67	-7.89
t.p.	182.42	

Typical Spring Tide Range

Average 3.15 to -3.45

stage	elevation ft	volume million ft ³
high	3.15	175.23
low	-3.45	7.94
t.p.	167.2829	

Effective/Potential Tidal Prism Ratio

date	potential	effective	ratio
8/2	188.1	163.08	0.87
8/7	190.13	163.67	0.86
9/1	202.16	166.13	0.82
9/4	182.42	148.83	0.82
	average	140.75	0.84

Typical Spring Tide Effective Tidal Prism Determination

Potential tidal prism for spring tide = 167.2829

Ratio of effective to potential = 0.84

Typical Spring Tidal Prism 140.75

Expected Maximum Elevation In Lagoon For Spring Tides

Date	Lagoon	Ocean	Ratio
8/2	3.14	3.53	0.89
8/7	3.50	3.58	0.98
9/1	3.28	3.51	0.93
9/4	3.13	3.08	1.02
	average	0.95	

Typical Spring Tide (Ocean High) = 3.15
Ratio of Ocean to Lagoon Tide Height = 0.95

Maximum Elevation In Lagoon At Individual Locations = 3.00 ft (NGVD)

Expected Minimum Elevation In Lagoon For Spring Tides

Date	Lagoon	Ocean	Ratio
8/2	-2.22	-3.37	0.66
8/7	-1.45	-3.22	0.45
9/1	-1.84	-3.52	0.52
9/4	-1.24	-3.67	0.34
	average	0.49	

Typical Spring Tide (Ocean Low) = -3.45
Ratio of Ocean to Lagoon Tide Height = 0.49

Minimum Elevation In Lagoon At Individual Locations = -1.70 ft (NGVD)

Expected Maximum Range In Lagoon For Spring Tides

Date	Lagoon	Ocean	Ratio
8/2	5.36	6.9	0.78
8/7	4.95	6.8	0.73
9/1	5.11	7.03	0.73
9/4	4.37	6.75	0.65
	average	0.72	

Typical Spring Tide (Ocean Range) = 6.6
Ratio of Ocean to Lagoon Tide Range = 0.72

Maximum Range In Lagoon At Individual Locations = 4.75 ft (NGVD)

APPENDIX 5

NEAP LAGOON TIDAL CONDITION (1968)

Typical Neap Tide Lagoon Condition Calculations 1968

Calculation of Effective Tidal Prism From Collected Data

7/26 6.4 ft	
Max. Elevation	
elevation ft	T.P. Lag. million ft ³
2.03	125.51
Min. Elevation	
elevation ft	T.P. Lag. million ft ³
-1.48	20.74
T.P. =	104.77

8/23 6.4 ft	
Max. Elevation	
elevation ft	T.P. Lag. million ft ³
2.35	140.1
Min. Elevation	
elevation ft	T.P. Lag. million ft ³
-0.90	28.28
T.P. =	111.82

9/7 6.4 ft	
Max. Elevation	
elevation ft	T.P. Lag. million ft ³
2.19	132.8
Min. Elevation	
elevation ft	T.P. Lag. million ft ³
-0.72	31.01
T.P. =	101.79

Calculation of Potential Tidal Prism (Lagoon Range = Ocean Range)

*Uniform Water Surface Elevation

7/26

stage	elevation ft	volume million ft ³
high	2.28	136.91
low	-2.42	13.27
t.p.	123.64	

8/23

stage	elevation ft	volume million ft ³
high	2.38	141.47
low	-1.92	16.22
t.p.	125.25	

9/7

stage	elevation ft	volume million ft ³
high	2.58	150.8
low	-2.35	13.68
t.p.	137.12	

Typical Neap Tide Range

Average 3.15 to -3.45

stage	elevation ft	volume million ft ³
high	2.25	133.29
low	-2.05	14.44
t.p.	118.84	

Effective/Potential Tidal Prism Ratio

date	potential	effective	ratio
7/26	123.64	104.77	0.85
8/23	125.25	111.82	0.89
9/7	137.12	101.79	0.74
	average	0.83	

Typical Neap Tide Effective Tidal Prism Determination

Potential tidal prism for spring tide =	118.84
Ratio of effective to Potential =	0.83
Typical Neap Tidal Prism	98.34

Expected Maximum Elevation In Lagoon For Neap Tides

Date	Lagoon	Ocean	Ratio
7/26	2.03	2.28	0.89
8/23	2.35	2.38	0.99
9/7	2.32	2.58	0.90
average		0.92	

Typical Spring Tide (Ocean High) = 2.25
 Ratio of Ocean to Lagoon Tide Height = 0.92

Maximum Elevation In Lagoon At Individual Locations = 2.08 ft (NGVD)

Expected Minimum Elevation In Lagoon For Neap Tides

Date	Lagoon	Ocean	Ratio
7/26	-1.6	-2.42	0.66
8/23	-1.01	-1.92	0.53
9/7	-0.96	-2.2	0.44
average		0.54	

Typical Spring Tide (Ocean Low) = -2.05
 Ratio of Ocean to Lagoon Tide Height = 0.54

Minimum Elevation In Lagoon At Individual Locations = -1.11 ft (NGVD)

Expected Maximum Range In Lagoon For Neap Tides

Date	Lagoon	Ocean	Ratio
7/26	3.63	4.7	0.77
8/23	3.36	4.3	0.78
9/7	3.28	4.78	0.69
average		0.75	

Typical Spring Tide (Ocean Range) = 4.3
 Ratio of Ocean to Lagoon Tide Range = 0.75

Maximum Range In Lagoon At Individual Locations = 3.21 ft (NGVD)

APPENDIX 6

HISTORICAL AND WITHOUT PROJECT LAGOON CONDITION SUMMARY

Past and Without Project Lagoon Volumes and Tidal Prisms for Key Elevations

Volumes Table

1968

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	4,295,559	9,229,551	98.61	341,835	1,012,308	1,286,417	23.24	47,645	75.37	294,190
Neap Low (Pot.)	-2.05	8,340,060	17,360,755	191.46	642,991	1,272,066	2,916,196	29.20	108,007	162.26	534,984
Measured Low	-1.68	10,611,054	20,684,206	243.60	766,082	1,316,077	3,369,152	30.21	124,783	213.38	641,298
1998 Low	-1.36	12,834,094	24,658,194	294.63	913,267	1,358,659	3,823,819	31.19	141,623	263.44	771,644
Neap High (Pot.)	2.25	46,828,325	142,825,507	1,075.03	5,289,834	1,767,521	9,537,170	40.58	353,229	1,034.45	4,936,605
1998 High	2.54	47,802,852	156,546,550	1,097.40	5,798,021	1,789,753	10,053,020	41.09	372,334	1,056.31	5,425,687
Measured High	2.99	49,279,978	178,866,377	1,131.31	6,624,681	1,820,857	10,883,665	41.80	403,099	1,089.51	6,221,582
Spring High (Pot.)	3.15	50,081,496	186,383,543	1,149.71	6,903,095	1,829,790	11,157,473	42.01	413,240	1,107.70	6,489,855
Upper Bound	7.00	56,137,432	392,494,589	1,288.73	14,536,838	1,890,591	18,375,316	43.40	680,567	1,245.33	13,856,271

1978

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	3,548,937	7,827,625	81.47	289,912	1,031,310	1,309,477	23.68	48,499	57.80	241,413
Neap Low (Pot.)	-2.05	5,388,500	13,972,225	123.70	517,490	1,306,624	2,977,530	30.00	110,279	93.71	407,211
Interpolated Low	-1.68	8,238,706	18,300,586	189.13	677,800	1,397,012	3,883,494	32.07	143,833	157.06	533,966
1998 Low	-1.36	8,370,548	18,466,676	192.16	683,951	1,399,631	3,911,460	32.13	144,869	160.03	539,082
Neap High (Pot.)	2.25	44,766,286	121,823,473	1,027.69	4,511,981	1,775,197	9,740,707	40.75	360,767	986.94	4,151,214
1998 High	2.54	45,807,125	134,956,495	1,051.58	4,998,389	1,788,196	10,257,450	41.05	379,906	1,010.53	4,618,484
Interpolated High	2.99	46,425,169	142,797,366	1,065.77	5,288,792	1,795,014	10,562,030	41.21	391,186	1,024.56	4,897,605
Spring High (Pot.)	3.15	47,768,204	163,524,847	1,096.60	6,056,476	1,810,520	11,355,354	41.56	420,569	1,055.04	5,635,908
Upper Bound	7.00	55,105,236	365,207,301	1,265.04	13,526,197	1,880,966	18,487,719	43.18	684,730	1,221.86	12,841,467

1988

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	4,136,684	11,335,290	94.96	419,826	1,044,066	1,328,372	23.97	49,199	71.00	370,627
Neap Low (Pot.)	-2.05	5,390,701	18,055,325	123.75	668,716	1,320,291	3,016,272	30.31	111,714	93.44	557,002
Interpolated Low	-1.68	6,965,434	22,678,242	159.90	839,935	1,422,604	4,045,729	32.66	149,842	127.25	690,093
1998 Low	-1.36	6,765,728	22,266,400	155.32	824,682	1,414,716	3,960,610	32.48	146,689	122.84	677,992
Neap High (Pot.)	2.25	43,064,271	117,040,833	988.62	4,334,846	1,780,444	9,845,188	40.87	364,637	947.74	3,970,209
1998 High	2.54	43,893,302	129,651,406	1,007.65	4,801,904	1,792,072	10,363,253	41.14	383,824	966.51	4,418,080
Interpolated High	2.98	44,131,342	133,612,544	1,013.11	4,948,613	1,795,317	10,524,687	41.21	389,803	971.90	4,558,810
Spring High (Pot.)	3.15	46,344,220	157,012,534	1,063.91	5,815,280	1,811,545	11,462,645	41.59	424,542	1,022.33	5,390,737
Upper Bound	7.00	54,811,904	354,818,172	1,258.30	13,141,415	1,871,927	18,573,666	42.97	687,914	1,215.33	12,453,501

1998

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	3,298,967	8,315,056	75.73	307,965	1,055,177	1,336,895	24.22	49,515	51.51	258,450
Neap Low (Pot.)	-2.05	4,903,340	13,776,741	112.56	510,250	1,345,126	3,050,507	30.88	112,982	81.69	397,268
Measured Low	-1.49	7,816,408	18,141,392	179.44	671,903	1,439,542	4,011,810	33.05	148,586	146.39	523,318
1998 Low	-1.36	7,816,408	18,141,392	179.44	671,903	1,439,542	4,011,810	33.05	148,586	146.39	523,318
Neap High (Pot.)	2.25	43,377,955	108,552,257	995.82	4,020,454	1,802,290	9,951,169	41.37	368,562	954.44	3,651,892
1998 High	2.54	45,154,168	121,392,621	1,036.59	4,496,023	1,815,280	10,475,771	41.67	387,992	994.92	4,108,032
Measured High	2.82	45,154,168	121,392,621	1,036.59	4,496,023	1,815,280	10,475,771	41.67	387,992	994.92	4,108,032
Spring High (Pot.)	3.15	48,265,310	150,007,915	1,108.01	5,555,849	1,836,934	11,590,037	42.17	429,261	1,065.84	5,126,588
Upper Bound	7.00	55,604,498	352,288,857	1,276.50	13,047,737	1,893,887	18,799,259	43.48	696,269	1,233.02	12,351,460

Past Lagoon Volume Summary Below Spring and Neap Tide Elevations

Elevation NGVD 29	Volume Below Elevations (million ft ³)					Rate of Infilling (million ft ³ /yr)			
	Year					Years			
feet	1968	1978	1988	1998	1998 (n)	68-78	78-88	88-98	68-98 (n)
-3.45	7.94	6.52	10.01	6.98	6.84	0.14	-0.35	0.30	0.04
-2.05	14.44	10.99	15.04	10.73	12.36	0.34	-0.40	0.43	0.07
2.25	133.29	112.08	107.20	98.60	120.16	2.12	0.49	0.86	0.44
3.15	175.23	152.17	145.55	138.42	161.01	2.31	0.66	0.71	0.47

Elevation NGVD 29	Volume Below Elevations (yds ³)					Rate of Infilling (yds ³ /yr)			
	Year					Years			
feet	1968	1978	1988	1998	1998 (n)	68-78	78-88	88-98	68-98 (n)
-3.45	294,190	241,413	370,627	258,450	253,328	5,278	-12,921	11,218	1,362
-2.05	534,984	407,211	557,002	397,268	457,788	12,777	-14,979	15,973	2,573
2.25	4,936,605	4,151,214	3,970,209	3,651,892	4,450,286	78,539	18,100	31,832	16,235
3.15	6,489,855	5,635,908	5,390,737	5,126,588	5,963,405	85,395	24,517	26,415	17,566

*Spring 3.15 to -3.45 NGVD

*Neap 2.25 to -2.05 NGVD

* n denotes normal rate of infilling (if lagoon had filled in at 3mm/year from 1968). 3mm/year taken from BLMP (1996)

Potential L.V Lost 1968 and 1998			
Tide	Actual	Normal	Difference
Spring	36.81	14.21	22.59
Neap	34.69	13.13	21.56

*Spring 3.15

*Neap 2.25

Predicted Lagoon Volume Summary Below Spring and Neap Tide Elevations

Elevation NGVD 29	Rate of Infilling (million cf/yr)					
	Years					
feet	98-08	08-18	18-28	28-38	38-48	48-58
-3.45	0.04	0.04	0.04	0.04	0.04	0.04
-2.05	0.07	0.07	0.07	0.07	0.07	0.07
2.25	0.66	0.63	0.59	0.56	0.53	0.50
3.15	0.66	0.63	0.59	0.56	0.53	0.50

Elevation NGVD 29	Tidal Volume (million cf)							
	Year							
feet	1998	2008	2018	2028	2038	2048	2058	2058 (n)
-3.45	6.98	6.58	6.18	5.78	5.38	4.98	4.58	4.63
-2.05	10.73	10.03	9.33	8.63	7.93	7.23	6.53	8.19
2.25	98.60	92.04	85.79	79.85	74.22	68.91	63.91	93.86
3.15	138.42	131.85	125.60	119.67	114.04	108.73	103.73	132.56

*Spring 3.15 to -3.45 NGVD

*Neap 2.25 to -2.05 NGVD

Potential L.V Lost 1998 and 2058			
Tide	Estimated		
	Predicted	Normal	Difference
Spring	34.69	5.86	28.83
Neap	34.69	4.74	29.95

*Spring 3.15

*Neap 2.25

Past Potential Tidal Prism

Tide Diurnal	Potential Tidal Prism (million cf)					Rate of Tidal Prism Loss (mcf/yr)			
	Year					Years			
	1968	1978	1988	1998	1998 (n)	68-78	78-88	88-98	68-98 (n)
Spring	167.28	145.65	135.54	131.44	154.17	2.16	1.01	0.41	0.44
Neap	118.84	101.09	92.16	87.87	107.80	1.78	0.89	0.43	0.37

Potential T.P. Lost 1968 and 1998			
Tide	Actual	Normal	Difference
Spring	35.84	13.11	22.73
Neap	30.97	11.05	19.92

*Spring 3.15 to -3.45 NGVD

*Neap 2.25 to -2.05 NGVD

Predicted Potential Tidal Prism

Tide Diurnal	Potential Tidal Prism (million cf)							
	Year							
	1998	2008	2018	2028	2038	2048	2058	2058 (n)
Spring	131.44	125.92	119.95	114.28	108.91	103.84	99.06	126.59
Neap	87.87	82.10	76.52	71.23	66.21	61.47	57.01	83.72

Potential T.P. Lost 1998 and 2058

Tide	Predicted	Normal	Difference
Spring	32.38	27.58	4.80
Neap	30.87	24.08	6.79

*Spring 3.15 to -3.45 NGVD

*Neap 2.25 to -2.05 NGVD

APPENDIX 7

LAGOON VOLUME AND ELEVATION

Lagoon Tidal Volume Below Defined Depths

Elevation	Tidal Volume (million cf)					Rate of Infilling (million cf/year)			
	Year					Years			
	1968	1978	1988	1998	1998 (n)	68-78	78-88	88-98	68-98 (n)
NGVD 29									
-20	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
-10	0.19	0.37	0.64	0.48	0.13	-0.02	-0.03	0.02	0.00
-5	3.90	4.03	5.93	4.07	3.30	-0.01	-0.19	0.19	0.02
-3.45	7.93	7.41	10.00	6.87	6.84	0.05	-0.26	0.31	0.04
-3	9.46	8.66	11.45	7.95	8.28	0.08	-0.28	0.35	0.04
-2.05	14.42	12.18	15.03	10.63	12.36	0.22	-0.28	0.44	0.07
-1.86	15.88	13.03	15.85	11.42	13.53	0.28	-0.28	0.44	0.08
-1	25.03	18.83	20.46	16.93	21.35	0.62	-0.16	0.35	0.12
0	47.47	33.57	32.42	29.78	39.49	1.39	0.11	0.26	0.27
1	81.15	65.05	59.90	54.39	70.41	1.61	0.52	0.55	0.36
2	122.13	103.11	97.00	89.08	109.51	1.90	0.61	0.79	0.42
2.25	133.31	113.74	107.23	99.27	120.16	1.96	0.65	0.80	0.44
2.44	141.93	121.97	115.12	107.28	128.49	2.00	0.68	0.78	0.45
3	168.00	146.93	138.88	132.15	154.00	2.11	0.80	0.67	0.47
3.1	172.83	151.51	143.35	136.75	158.66	2.13	0.82	0.66	0.47
3.15	175.24	153.80	145.57	139.07	161.01	2.14	0.82	0.65	0.47
4	216.87	193.89	184.54	179.45	202.11	2.30	0.94	0.51	0.49
4.1	221.88	198.82	189.29	184.37	207.04	2.31	0.95	0.49	0.49
4.3	231.94	208.72	198.87	194.25	216.96	2.32	0.99	0.46	0.50
5	267.62	243.84	232.96	229.28	252.26	2.38	1.09	0.37	0.51
6	319.61	295.11	283.50	280.53	303.96	2.45	1.16	0.30	0.52
6.6	351.28	326.39	314.57	311.95	335.45	2.49	1.18	0.26	0.53
7	372.51	347.37	335.43	333.06	356.61	2.51	1.19	0.24	0.53

APPENDIX 8

LAGOON BOTTOM SURFACE AREA AND ELEVATION

Bolinas Lagoon Surface Areas at Defined Depth Contours

Depth ft-NGVD	Lagoon Surface Area (million ft ²)					Year
	1968	1978	1988	1998	1998 (n)	
-5	1.87	1.61	2.17	1.47	1.77	1.78
-3.45	3.28	2.72	3.09	2.28	4.43	2.84
-3	3.73	3.06	3.41	2.53	5.21	3.18
-2.05	7.06	4.30	4.06	3.17	6.84	4.65
-1.86	8.27	4.65	4.52	4.71	12.30	5.54
-1	13.93	9.36	7.44	8.54	25.13	9.81
0	29.10	21.83	17.43	17.73	35.73	21.53
1	37.23	35.08	32.80	29.67	42.40	33.70
2	43.25	40.94	39.67	39.21	44.60	40.77
2.25	45.07	42.98	41.28	41.58	45.15	42.73
2.44	45.68	43.65	41.82	42.73	47.18	43.47
3	47.44	45.41	43.29	45.88	48.74	45.51
3.15	48.23	45.91	44.51	46.39	49.96	46.26
4	49.69	48.72	47.30	48.72	51.86	48.61
4.1	50.12	49.35	47.66	49.26	53.16	49.10
4.3	50.44	49.67	48.10	49.57	54.92	49.45
5	51.43	50.68	49.53	50.55		50.55
6	52.40	51.77	51.37	51.86		51.85
7	53.17	52.56	52.31	52.93		52.74

APPENDIX 9

LAGOON SEDIMENTATION RATE WORK SHEET

Spring Tide

Year	Infill Rate
	million ft ³ /yr
1973	2.31
1983	0.66
1993	0.71

Neap Tide

Year	Infill Rate
	million ft ³ /yr
1973	2.12
1983	0.49
1993	0.86

APPENDIX 10

HISTORICAL AND *WITHOUT PROJECT* POTENTIAL AND EFFECTIVE LAGOON TIDAL PRISMS

Potential T.P., Effective T.P., and Volume

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume	Potential	% of Pot.	Effective	Volume (n)	Potential (n)	% of Pot.	Effective (n)
	million ft ³	million ft ³		million ft ³	million ft ³	million ft ³		million ft ³
1968	175.23	167.28	0.84	140.75	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50	170.49	162.91	0.82	133.15
1988	145.55	135.54	0.69	93.62	165.75	158.54	0.79	125.77
1998	138.42	131.44	0.65	86.03	161.01	154.17	0.77	118.59
2008	131.85	125.92	0.62	78.23	156.27	149.58	0.75	111.46
2018	125.60	119.95	0.59	70.71	151.53	144.98	0.72	104.54
2028	119.67	114.28	0.56	63.92	146.78	140.38	0.70	97.85
2038	114.04	108.91	0.53	57.81	142.04	135.78	0.67	91.37
2048	108.73	103.84	0.50	52.32	137.30	131.19	0.65	85.12
2058	103.73	99.06	0.48	47.40	132.56	126.59	0.62	79.09

*n denotes lagoon condition if normal infilling had occurred

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume	Potential	% of Pot.	Effective	Volume (n)	Potential (n)	Effective (n)	
	million ft ³	million ft ³		million ft ³	million ft ³	million ft ³		million ft ³
1968	133.29	118.84	0.83	98.34	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46	128.91	115.16	0.81	93.84
1988	107.20	92.16	0.75	69.32	124.53	111.48	0.80	89.43
1998	98.60	87.87	0.73	63.92	120.16	107.80	0.79	85.12
2008	92.04	82.10	0.71	58.16	115.77	105.47	0.78	81.95
2018	85.79	76.52	0.69	52.83	111.39	103.15	0.76	78.84
2028	79.85	71.23	0.67	47.95	107.01	100.83	0.75	75.78
2038	74.22	66.21	0.66	43.50	102.62	98.50	0.74	72.79
2048	68.91	61.47	0.64	39.44	98.24	96.18	0.73	69.86
2058	63.91	57.01	0.63	35.76	93.86	93.86	0.71	66.98

*n denotes lagoon condition if normal infilling had occurred

Tidal Prism (Measured)

Year	million ft ³		million yds ³	
	Potential	Effective	Potential	Effective
1968	167.28	140.75	6.20	5.21
1998	131.44	86.03	4.87	3.19
Change	35.84	54.71	1.33	2.03
% Change ¹	21.43%	38.87%	21.43%	38.87%

¹ Percent change from 1968 levels

Tidal Prism (Predicted)

Year	million ft ³		million yds ³	
	Potential	Effective	Potential	Effective
1998	131.44	86.03	4.87	3.19
2058	99.06	47.40	3.67	1.76
Change	32.38	38.64	1.20	1.43
% Change ²	24.63%	44.91%	24.63%	44.91%

²Percent change from 1998 levels

APPENDIX 11

HISTORICAL AND WITHOUT PROJECT LAGOON WATER SURFACE ELEVATIONS

Past and Future Without Project Water Depths and Tide Ranges in Lagoon

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	131.85	3.15	-3.45	0.78	0.32	2.46	-1.09	3.55
2018	125.60	3.15	-3.45	0.75	0.29	2.38	-1.01	3.38
2028	119.67	3.15	-3.45	0.73	0.27	2.30	-0.92	3.22
2038	114.04	3.15	-3.45	0.71	0.24	2.23	-0.84	3.07
2048	108.73	3.15	-3.45	0.69	0.22	2.16	-0.77	2.93
2058	103.73	3.15	-3.45	0.67	0.20	2.10	-0.70	2.80

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.86	0.62	1.93	-1.26	3.19
1988	107.20	2.25	-2.05	0.84	0.63	1.90	-1.30	3.19
1998	98.60	2.25	-2.05	0.82	0.66	1.84	-1.36	3.20
2008	92.04	2.25	-2.05	0.80	0.69	1.79	-1.41	3.20
2018	85.79	2.25	-2.05	0.78	0.71	1.75	-1.45	3.20
2028	79.85	2.25	-2.05	0.76	0.73	1.70	-1.49	3.20
2038	74.22	2.25	-2.05	0.74	0.75	1.67	-1.53	3.20
2048	68.91	2.25	-2.05	0.72	0.77	1.63	-1.57	3.20
2058	63.91	2.25	-2.05	0.71	0.78	1.59	-1.61	3.20

APPENDIX 12

LAGOON INLET CROSS-SECTIONAL DATA

Fall Condition

Summary

year	area (ft ²)
1967	1197.2
1998	1049.6

Area Loss (ft²/yr)

Years
67-98
4.8

Oct. 1967			
x distance	x standard	depth	Area
ft	ft	NGVD	ft ²
87	0	0	
90	3	-0.34	0.51
100	13	-1.4	8.7
110	23	-2.6	20
120	33	-4	33
130	43	-6	50
140	53	-7.3	66.5
150	63	-9	81.5
160	73	-10.2	96
170	83	-11.1	106.5
180	93	-11.2	111.5
190	103	-10.8	110
200	113	-9.5	101.5
210	123	-9.3	94
220	133	-8.5	89
230	143	-7.5	80
240	153	-5.5	65
250	163	-3	42.5
260	173	-1.6	23
270	183	-1	13
281	194	0	5.5
total area (ft²)		1197.2	

Fall 1998			
x distance	x standard	depth	Area
ft	ft	NGVD	ft ²
52	0	0	
60	8	-0.4	1.6
70	18	-0.9	6.5
80	28	-2	14.5
90	38	-3.6	28
100	48	-5.6	46
110	58	-7	63
120	68	-8	75
130	78	-8.6	83
140	88	-8.8	87
150	98	-9.2	90
160	108	-9.2	92
170	118	-8.9	90.5
180	128	-8.6	87.5
190	138	-7.8	82
200	148	-6.4	71
210	158	-5	57
220	168	-3.2	41
230	178	-2	26
238	186	0	8
total area (ft²)		1049.6	

Spring Condition

Summary

year	area (ft ²)
1958	1388.1
1967	1342
1998	1130.5

Area Loss (ft²/yr)

Years	
58-67	67-98
5.1	6.8

May-58

x-location	x-standard	depth	Area
ft	ft	NGVD	ft ²
88	0	0	
100	12	-1.1	6.6
110	22	-2.3	17
120	32	-3.6	29.5
130	42	-5.2	44
140	52	-7	61
150	62	-8.3	76.5
160	72	-9.6	89.5
170	82	-10.4	100
180	92	-10.9	106.5
190	102	-10.5	107
200	112	-9.2	98.5
210	122	-9.5	93.5
220	132	-8	87.5
230	142	-8	80
240	152	-8.2	81
250	162	-7.3	77.5
260	172	-6.9	71
270	182	-5.9	64
280	192	-5.2	55.5
290	202	-2	36
296	208	0	6
total area (ft²)			1388.1

Jun-67

x-location	x standard	depth	Area
ft	ft	NGVD	ft ²
88	0	0	
100	12	-0.5	3
110	22	-1.6	10.5
120	32	-2.6	21
130	42	-4	33
140	52	-5.8	49
150	62	-6.8	63
160	72	-8.1	74.5
170	82	-9.7	89
180	92	-10.1	99
190	102	-10.5	103
200	112	-10.7	106
210	122	-11.3	110
220	132	-10.9	111
230	142	-9.9	104
240	152	-9.3	96
250	162	-7.5	84
260	172	-6.5	70
270	182	-4.8	56.5
280	192	-2.9	38.5
290	202	-1	19.5
293	205	0	1.5
total area (ft²)			1342

Apr-98

x-location	x-standard	depth	Area
ft	ft	NGVD	ft ²
65	0	0	
70	5	-1	2.5
80	15	-3.2	21
90	25	-5	41
100	35	-6.5	57.5
110	45	-7.3	69
120	55	-7.6	74.5
130	65	-7.5	75.5
140	75	-7	72.5
150	85	-6.5	67.5
160	95	-5.8	61.5
170	105	-5.1	54.5
180	115	-4.9	50
190	125	-4.8	48.5
200	135	-4.9	48.5
210	145	-5	49.5
220	155	-5.2	51
230	165	-5.5	53.5
240	175	-5.8	56.5
250	185	-5.4	56
260	195	-4.8	51
270	205	-3	39
280	215	-1.5	22.5
290	225	0	7.5
total area (ft²)			1130.5

APPENDIX 13

SAEABERGH AND KRAUS INLET STABILITY ANALYSIS INPUT

Seabergh and Kraus 1997 Inlet Stability Program Inputs	
fundemental ocean tide	3.3 ft
tidal period	12.42 hours
basin surface area	30 million ft ²
hydrualic radius	5.53 ft
channel length	1000 ft
channel width	190 ft
calibration channel area	1050 ft ²
Ken	0.05
Kex	1
Manning's	0.03

APPENDIX 14
O'BRIEN CLOSURE INDEX ANALYSIS

Potential Closure has been estimated at a Closure Index of 15

Without Project Estimate - Zero Fresh Water Flow

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	82.10	250	4.3	0	4,017	45,000	11.2
2018	76.52	250	4.3	0	3,744	45,000	12.0
2028	71.23	250	4.3	0	3,485	45,000	12.9
2038	66.21	250	4.3	0	3,239	45,000	13.9
2048	61.47	250	4.3	0	3,007	45,000	15.0
2058	57.01	250	4.3	0	2,789	45,000	16.1

Without Project Estimate - 700 ft³/sec Fresh Water Flow

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	700	6,585	45,000	6.8
1978	101.09	250	4.3	700	5,716	45,000	7.9
1988	92.16	250	4.3	700	5,279	45,000	8.5
1998	87.87	250	4.3	700	5,070	45,000	8.9
2008	82.10	250	4.3	700	4,787	45,000	9.4
2018	76.52	250	4.3	700	4,514	45,000	10.0
2028	71.23	250	4.3	700	4,255	45,000	10.6
2038	66.21	250	4.3	700	4,010	45,000	11.2
2048	61.47	250	4.3	700	3,778	45,000	11.9
2058	57.01	250	4.3	700	3,560	45,000	12.6

Without Project Estimate - Reduced Inlet Width

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	225	4.3	0	6,460	45,000	7.0
1978	101.09	225	4.3	0	5,495	45,000	8.2
1988	92.16	225	4.3	0	5,010	45,000	9.0
1998	87.87	225	4.3	0	4,777	45,000	9.4
2008	82.10	225	4.3	0	4,463	45,000	10.1
2018	76.52	225	4.3	0	4,160	45,000	10.8
2028	71.23	225	4.3	0	3,872	45,000	11.6
2038	66.21	225	4.3	0	3,599	45,000	12.5
2048	61.47	225	4.3	0	3,341	45,000	13.5
2058	57.01	225	4.3	0	3,099	45,000	14.5

Without Project Estimate - 700 ft³/sec Fresh Water Flow and Reduced Inlet Width

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	225	4.3	700	7,317	45,000	6.2
1978	101.09	225	4.3	700	6,351	45,000	7.1
1988	92.16	225	4.3	700	5,866	45,000	7.7
1998	87.87	225	4.3	700	5,633	45,000	8.0
2008	82.10	225	4.3	700	5,319	45,000	8.5
2018	76.52	225	4.3	700	5,016	45,000	9.0
2028	71.23	225	4.3	700	4,728	45,000	9.5
2038	66.21	225	4.3	700	4,455	45,000	10.1
2048	61.47	225	4.3	700	4,198	45,000	10.7
2058	57.01	225	4.3	700	3,955	45,000	11.4

APPENDIX 15

HISTORICAL AND PROJECT HABITAT LEVELS

Historical and Projected Volumes and Habitats

Year	Lagoon Volume (3.15' NGVD) yds ³	Upland acres	Upland yds ³	Intertidal acres	Intertidal yds ³	Subtidal acres	Subtidal yds ³
1968	6,489,855	155.82	7,634,688	876.12	5,580,284	213.38	641,298
1978	5,635,908	197.29	7,943,862	867.50	4,363,639	157.06	533,966
1988	5,390,737	243.43	7,894,691	844.65	3,868,717	127.25	690,093
1998	5,126,588	238.10	8,243,436	848.53	3,584,714	146.39	523,318

Without Project

Year	Lagoon Volume yds ³	Upland acres	Upland yds ³	Intertidal acres	Intertidal yds ³	Subtidal acres	Subtidal yds ³
2008	4,883,508	252.77	8,351,980	843.61	3,228,889	134.45	502,281
2018	4,652,007	266.74	8,455,354	838.92	2,890,014	123.07	482,246
2038	4,223,741	292.59	8,646,590	830.25	2,263,112	102.03	445,183
2058	3,841,791	315.64	8,817,144	822.52	1,704,008	83.26	412,128

APPENDIX 16
POTENTIAL TIDAL PRISM INCREASE FOR EACH
RESTORATION COMPONENT

**Potential Spring Tidal Prism Increase in Lagoon
Resulting From Each Component**

	1998 Volumes yds ³	Constructed Volumes yds ³	Change in Volume yds ³
Bolinas Channel			
3.15	45,022	175,850	130,827
-3.45	51	22,895	22,844
Potential Tidal Prism	44,971	152,954	107,983
Pine Gulch Delta			
3.15	212,823	379,022	166,199
-3.45	0	0	0
Potential Tidal Prism	212,823	379,022	166,199
Pine Gulch Delta (mod.)			
3.15	210,703	366,184	155,482
-3.45	0	0	0
Potential Tidal Prism	210,703	366,184	155,482
Kent Island			
3.15	106,867	404,604	297,737
-3.45	0	0	0
Potential Tidal Prism	106,867	404,604	297,736
Dipsea Road Fill			
3.15	5,640	22,148	16,508
-3.45	0	0	0
Potential Tidal Prism	5,640	22,148	16,508
Highway 1 Fills			
3.15	3,678	6,676	2,998
-3.45	0	0	0
Potential Tidal Prism	3,678	6,676	2,998
South Arm Channel			
3.15	104,925	194,030	89,106
-3.45	97	12,914	12,817
Potential Tidal Prism	104,827	181,116	76,289
Seadrift Lagoon			
3.15	0	473,177	473,177
-3.45	0	75,331	75,331
Potential Tidal Prism	0	397,846	397,846
Main Channel			
3.15	166,037	382,278	216,241
-3.45	15	10,891	10,876
Potential Tidal Prism	166,022	371,387	205,365
North End			
3.15	841,715	1,366,123	524,408
-3.45	249	35,955	35,707
Potential Tidal Prism	841,467	1,330,168	488,701

**Potential Neap Tidal Prism Increase in Lagoon
Resulting From Each Component**

	1998 Volumes yds ³	Constructed Volumes yds ³	Change in Volume yds ³
Bolinas Channel			
2.25	25,468	153,431	127,963
-2.05	228	51,549	51,320
Potential Tidal Prism	25,239	101,882	76,643
Pine Gulch Delta			
2.25	105,190	255,382	150,192
-2.05	0	51	51
Potential Tidal Prism	105,190	255,331	150,140
Pine Gulch Delta (mod.)			
2.25	104,773	249,215	144,442
-2.05	0	52	52
Potential Tidal Prism	104,773	249,163	144,390
Kent Island			
2.25	27,763	242,483	214,720
-2.05	0	105	105
Potential Tidal Prism	27,763	242,378	214,615
Dipsea Road Fill			
2.25	2,699	15,162	12,463
-2.05	0	226	226
Potential Tidal Prism	2,699	14,937	12,238
Highway 1 Fills			
2.25	1,430	3,666	2,236
-2.05	0	0	0
Potential Tidal Prism	1,430	3,666	2,236
South Arm Channel			
2.25	79,510	168,339	88,829
-2.05	873	48,085	47,212
Potential Tidal Prism	78,637	120,254	41,617
Seadrift Lagoon			
2.25	0	412,149	412,149
-2.05	0	147,966	147,966
Potential Tidal Prism	0	264,184	264,184
Main Channel			
2.25	111,608	327,886	216,279
-2.05	696	71,583	70,887
Potential Tidal Prism	110,911	256,303	145,392
North End			
2.25	644,286	1,102,619	458,332
-2.05	2,251	186,673	184,422
Potential Tidal Prism	642,035	915,945	273,910

APPENDIX 17

VOLUMES AND SURFACE AREAS AT DEFINING DEPTHS FOR RESTORATION ALTERNATIVES

Volumes and Surface Areas at Defining Depths

1968

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	4,295,559	9,229,551	98.61	341,835	1,012,308	1,286,417	23.24	47,645	75.37	294,190
Neap Low (Pot.)	-2.05	8,340,060	17,360,755	191.46	642,991	1,272,066	2,916,196	29.20	108,007	162.26	534,984
Measured Low	-1.70	10,611,054	20,684,206	243.60	766,082	1,316,077	3,369,152	30.21	124,783	213.38	641,298
1998 Low	-1.36	12,834,094	24,658,194	294.63	913,267	1,358,659	3,823,819	31.19	141,623	263.44	771,644
Neap High (Pot.)	2.25	46,828,325	142,825,507	1,075.03	5,289,834	1,767,521	9,537,170	40.58	353,229	1,034.45	4,936,605
1998 High	2.54	47,802,852	156,546,550	1,097.40	5,798,021	1,789,753	10,053,020	41.09	372,334	1,056.31	5,425,687
Measured High	3.00	49,279,978	178,866,377	1,131.31	6,624,681	1,820,857	10,883,665	41.80	403,099	1,089.51	6,221,582
Spring High (Pot.)	3.15	50,081,496	186,383,543	1,149.71	6,903,095	1,829,790	11,157,473	42.01	413,240	1,107.70	6,489,855
Upper Bound	7.00	56,137,432	392,494,589	1,288.73	14,536,838	1,890,591	18,375,316	43.40	680,567	1,245.33	13,856,271

1978

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	3,548,937	7,827,625	81.47	289,912	1,031,310	1,309,477	23.68	48,499	57.80	241,413
Neap Low (Pot.)	-2.05	5,388,500	13,972,225	123.70	517,490	1,306,624	2,977,530	30.00	110,279	93.71	407,211
Interpolated Low	-1.38	8,238,706	18,300,586	189.13	677,800	1,397,012	3,883,494	32.07	143,833	157.06	533,966
1998 Low	-1.36	8,370,548	18,466,676	192.16	683,951	1,399,631	3,911,460	32.13	144,869	160.03	539,082
Neap High (Pot.)	2.25	44,766,286	121,823,473	1,027.69	4,511,981	1,775,197	9,740,707	40.75	360,767	986.94	4,151,214
1998 High	2.54	45,807,125	134,956,495	1,051.58	4,998,389	1,788,196	10,257,450	41.05	379,906	1,010.53	4,618,484
Interpolated High	2.71	46,425,169	142,797,366	1,065.77	5,288,792	1,795,014	10,562,030	41.21	391,186	1,024.56	4,897,605
Spring High (Pot.)	3.15	47,768,204	163,524,847	1,096.60	6,056,476	1,810,520	11,355,354	41.56	420,569	1,055.04	5,635,908
Upper Bound	7.00	55,105,236	365,207,301	1,265.04	13,526,197	1,880,966	18,487,719	43.18	684,730	1,221.86	12,841,467

1988

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	4,136,684	11,335,290	94.96	419,826	1,044,066	1,328,372	23.97	49,199	71.00	370,627
Neap Low (Pot.)	-2.05	5,390,701	18,055,325	123.75	668,716	1,320,291	3,016,272	30.31	111,714	93.44	557,002
Interpolated Low	-1.30	6,965,434	22,678,242	159.90	839,935	1,422,604	4,045,729	32.66	149,842	127.25	690,093
1998 Low	-1.36	6,765,728	22,266,400	155.32	824,682	1,414,716	3,960,610	32.48	146,689	122.84	677,992
Neap High (Pot.)	2.25	43,064,271	117,040,833	988.62	4,334,846	1,780,444	9,845,188	40.87	364,637	947.74	3,970,209
1998 High	2.54	43,893,302	129,651,406	1,007.65	4,801,904	1,792,072	10,363,253	41.14	383,824	966.51	4,418,080
Interpolated High	2.63	44,131,342	133,612,544	1,013.11	4,948,613	1,795,317	10,524,687	41.21	389,803	971.90	4,558,810
Spring High (Pot.)	3.15	46,344,220	157,012,534	1,063.91	5,815,280	1,811,545	11,462,645	41.59	424,542	1,022.33	5,390,737
Upper Bound	7.00	54,811,904	354,818,172	1,258.30	13,141,415	1,871,927	18,573,666	42.97	687,914	1,215.33	12,453,501

1998

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	3,298,967	8,315,056	75.73	307,965	1,055,177	1,336,895	24.22	49,515	51.51	258,450
Neap Low (Pot.)	-2.05	4,903,340	13,776,741	112.56	510,250	1,345,126	3,050,507	30.88	112,982	81.69	397,268
Measured Low	-1.36	7,816,408	18,141,392	179.44	671,903	1,439,542	4,011,810	33.05	148,586	146.39	523,318
1998 Low	-1.36	7,816,408	18,141,392	179.44	671,903	1,439,542	4,011,810	33.05	148,586	146.39	523,318
Neap High (Pot.)	2.25	43,377,955	108,552,257	995.82	4,020,454	1,802,290	9,951,169	41.37	368,562	954.44	3,651,892
1998 High	2.54	45,154,168	121,392,621	1,036.59	4,496,023	1,815,280	10,475,771	41.67	387,992	994.92	4,108,032
Measured High	2.54	45,154,168	121,392,621	1,036.59	4,496,023	1,815,280	10,475,771	41.67	387,992	994.92	4,108,032
Spring High (Pot.)	3.15	48,265,310	150,007,915	1,108.01	5,555,849	1,836,934	11,590,037	42.17	429,261	1,065.84	5,126,588
Upper Bound	7.00	55,604,498	352,288,857	1,276.50	13,047,737	1,893,887	18,799,259	43.48	696,269	1,233.02	12,351,468

North, Central (Estuarine), South (Seadrift)

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	7,029,119	11,236,314	161.37	416,160	0	0	0.00	0	161.37	416,160
Neap Low (Pot.)	-2.05	11,602,494	24,318,880	266.36	900,699	0	0	0.00	0	266.36	900,699
Predicted Low	-1.91	13,111,265	26,067,597	300.99	965,467	0	0	0.00	0	300.99	965,467
1998 Low	-1.36	16,206,213	34,029,397	372.04	1,260,348	0	0	0.00	0	372.04	1,260,348
Neap High (Pot.)	2.25	47,753,954	145,635,317	1,096.28	5,393,901	0	0	0.00	0	1,096.28	5,393,901
1998 High	2.54	48,862,900	159,646,749	1,121.73	5,912,843	0	0	0.00	0	1,121.73	5,912,843
Predicted High	3.15	50,675,144	190,075,898	1,163.34	7,039,849	0	0	0.00	0	1,163.34	7,039,849
Spring High (Pot.)	3.15	50,675,144	190,075,898	1,163.34	7,039,849	0	0	0.00	0	1,163.34	7,039,849

Bolinas Lagoon Ecosystem Restoration Project
Technical Appendices: Engineering Appendix

North, Central (Estuarine), South (No Seadrift)

Tide Condition	Bolinas Lagoon					Seadrift Lagoon				Actual or Total	
	Tide Elev. ft-NGVD	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	7,029,119	11,236,314	161.37	416,160	1,325,379	2,029,123	30.43	75,153	130.94	341,007
Neap Low (Pot.)	-2.05	11,602,494	24,318,880	266.36	900,699	1,463,307	3,984,538	33.59	147,575	232.76	753,124
Predicted Low	-1.73	13,885,414	28,497,539	318.76	1,055,464	1,493,677	4,457,648	34.29	165,098	284.47	890,366
1998 Low	-1.36	16,206,213	34,029,397	372.04	1,260,348	1,528,548	5,016,771	35.09	185,806	336.95	1,074,542
Neap High (Pot.)	2.25	47,753,954	145,635,317	1,096.28	5,393,901	1,812,485	11,107,009	41.61	411,371	1,054.67	4,982,530
1998 High	2.54	48,862,900	159,646,749	1,121.73	5,912,843	1,823,800	11,634,310	41.87	430,900	1,079.86	5,481,943
Predicted High	3.03	50,511,662	184,004,579	1,159.58	6,814,985	1,839,951	12,532,072	42.24	464,151	1,117.34	6,350,834
Spring High (Pot.)	3.15	50,675,144	190,075,898	1,163.34	7,039,849	1,843,374	12,753,073	42.32	472,336	1,121.02	6,567,513
Upper Bound	7.00	55,686,581	395,804,175	1,278.38	14,659,415	1,897,835	19,982,419	43.57	740,090	1,234.81	13,919,325

North, Central (Riparian), and South (Seadrift)

Tide Condition	Bolinas Lagoon					Seadrift Lagoon				Actual or Total	
	Tide Elev. ft-NGVD	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	7,029,649	11,237,106	161.38	416,189	0	0	0.00	0	161.38	416,189
Neap Low (Pot.)	-2.05	11,602,493	24,319,738	266.36	900,731	0	0	0.00	0	266.36	900,731
Predicted Low	-1.90	13,153,349	26,199,778	301.96	970,362	0	0	0.00	0	301.96	970,362
1998 Low	-1.36	16,205,345	34,030,160	372.02	1,260,376	0	0	0.00	0	372.02	1,260,376
Neap High (Pot.)	2.25	47,672,455	145,547,520	1,094.40	5,390,649	0	0	0.00	0	1,094.40	5,390,649
1998 High	2.54	48,734,293	159,528,433	1,118.78	5,908,461	0	0	0.00	0	1,118.78	5,908,461
Predicted High	3.15	50,470,579	189,851,066	1,158.64	7,031,522	0	0	0.00	0	1,158.64	7,031,522
Spring High (Pot.)	3.15	50,470,579	189,851,066	1,158.64	7,031,522	0	0	0.00	0	1,158.64	7,031,522
Upper Bound	7.00	55,679,987	395,042,952	1,278.23	14,631,222	0	0	0.00	0	1,278.23	14,631,222

North, Central (Riparian), and South (No Seadrift)

Tide Condition	Bolinas Lagoon					Seadrift Lagoon				Actual or Total	
	Tide Elev. ft-NGVD	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	7,029,649	11,237,106	161.38	416,189	1,325,379	2,029,123	30.43	75,153	130.95	341,036
Neap Low (Pot.)	-2.05	11,602,493	24,319,738	266.36	900,731	1,463,307	3,984,538	33.59	147,575	232.76	753,156
Predicted Low	-1.72	13,926,295	28,637,457	319.70	1,060,647	1,494,624	4,472,590	34.31	165,651	285.39	894,995
1998 Low	-1.36	16,205,345	34,030,160	372.02	1,260,376	1,528,548	5,016,771	35.09	185,806	336.93	1,074,570
Neap High (Pot.)	2.25	47,672,455	145,547,520	1,094.40	5,390,649	1,812,485	11,107,009	41.61	411,371	1,052.80	4,979,279
1998 High	2.54	48,734,293	159,528,433	1,118.78	5,908,461	1,823,800	11,634,310	41.87	430,900	1,076.91	5,477,561
Predicted High	3.03	50,309,213	183,804,170	1,154.94	6,807,562	1,839,951	12,532,072	42.24	464,151	1,112.70	6,343,412
Spring High (Pot.)	3.15	50,470,579	189,851,066	1,158.64	7,031,522	1,843,374	12,753,073	42.32	472,336	1,116.32	6,559,185
Upper Bound	7.00	55,679,987	395,042,952	1,278.23	14,631,222	1,897,835	19,982,419	43.57	740,090	1,234.66	13,891,132

North and Central (Estuarine)

Tide Condition	Bolinas Lagoon					Seadrift Lagoon				Actual or Total	
	Tide Elev. ft-NGVD	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	6,115,082	10,194,890	140.38	377,589	1,055,177	1,336,895	24.22	49,515	116.16	328,074
Neap Low (Pot.)	-2.05	10,792,024	22,080,018	247.75	817,779	1,345,126	3,050,507	30.88	112,982	216.87	704,797
Predicted Low	-1.68	13,286,281	26,658,585	305.01	987,355	1,397,008	3,557,831	32.07	131,772	272.94	855,584
1998 Low	-1.36	15,456,075	31,239,890	354.82	1,157,033	1,439,542	4,011,810	33.05	148,586	321.77	1,008,448
Neap High (Pot.)	2.25	47,587,066	141,396,660	1,092.44	5,236,914	1,802,290	9,951,169	41.37	368,562	1,051.07	4,868,352
1998 High	2.54	48,704,037	155,361,162	1,118.09	5,754,118	1,815,280	10,475,771	41.67	387,992	1,076.41	5,366,126
Predicted High	2.99	50,099,074	177,631,428	1,150.11	6,578,942	1,831,891	11,296,526	42.05	418,390	1,108.06	6,160,552
Spring High (Pot.)	3.15	50,519,484	185,695,377	1,159.76	6,877,607	1,836,934	11,590,037	42.17	429,261	1,117.59	6,448,346
Upper Bound	7.00	55,634,062	390,851,438	1,277.18	14,447,754	1,893,887	18,799,259	43.48	696,269	1,233.70	13,779,711

North and Central (Riparian)

Tide Condition	Bolinas Lagoon					Seadrift Lagoon				Actual or Total	
	Tide Elev. ft-NGVD	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	6,115,082	10,194,890	140.38	377,589	1,055,177	1,336,895	24.22	49,515	116.16	328,074
Neap Low (Pot.)	-2.05	10,792,027	22,080,019	247.75	817,779	1,345,126	3,050,507	30.88	112,982	216.87	704,797
Predicted Low	-1.68	13,286,290	26,658,588	305.01	987,355	1,397,008	3,557,831	32.07	131,772	272.94	855,584
1998 Low	-1.36	15,455,207	31,239,796	354.80	1,157,030	1,439,542	4,011,810	33.05	148,586	321.75	1,008,444
Neap High (Pot.)	2.25	47,505,571	141,308,008	1,090.57	5,233,630	1,802,290	9,951,169	41.37	368,562	1,049.20	4,865,069
1998 High	2.54	48,575,432	155,241,992	1,115.13	5,749,704	1,815,280	10,475,771	41.67	387,992	1,073.46	5,361,712
Predicted High	2.99	49,899,524	177,438,235	1,145.53	6,571,787	1,831,891	11,296,526	42.05	418,390	1,103.48	6,153,397
Spring High (Pot.)	3.15	50,314,939	185,469,694	1,155.07	6,869,248	1,836,934	11,590,037	42.17	429,261	1,112.90	6,439,988
Upper Bound	7.00	55,627,463	390,089,331	1,277.03	14,447,754	1,893,887	18,799,259	43.48	696,269	1,233.55	13,751,485

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North and South (Seadrift)

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	6,505,565	10,620,234	149.35	393,342	0	0	0.00	0	149.35	393,342
Neap Low (Pot.)	-2.05	11,039,663	22,955,226	253.43	850,194	0	0	0.00	0	253.43	850,194
Predicted Low	-1.67	12,878,109	27,535,055	295.64	1,019,817	0	0	0.00	0	295.64	1,019,817
1998 Low	-1.36	14,717,978	31,811,906	337.88	1,178,219	0	0	0.00	0	337.88	1,178,219
Neap High (Pot.)	2.25	43,584,472	131,798,783	1,000.56	4,881,437	0	0	0.00	0	1,000.56	4,881,437
1998 High	2.54	45,330,494	144,692,993	1,040.64	5,359,000	0	0	0.00	0	1,040.64	5,359,000
Predicted High	2.98	47,825,707	165,226,072	1,097.92	6,119,485	0	0	0.00	0	1,097.92	6,119,485
Spring High (Pot.)	3.15	48,426,171	173,409,813	1,111.71	6,422,586	0	0	0.00	0	1,111.71	6,422,586
Upper Bound	7.00	55,657,142	376,264,888	1,277.71	13,935,738	0	0	0.00	0	1,277.71	13,935,738

North and South (No Seadrift)

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	6,505,565	10,620,234	149.35	393,342	1,325,379	2,029,123	30.43	75,153	118.92	318,189
Neap Low (Pot.)	-2.05	11,039,663	22,955,226	253.43	850,194	1,463,307	3,984,538	33.59	147,575	219.84	702,618
Predicted Low	-1.49	14,266,510	29,929,146	327.51	1,108,487	1,516,339	4,818,853	34.81	178,476	292.70	930,011
1998 Low	-1.36	14,717,978	31,811,906	337.88	1,178,219	1,528,548	5,016,771	35.09	185,806	302.79	992,412
Neap High (Pot.)	2.25	43,584,472	131,798,783	1,000.56	4,881,437	1,812,485	11,107,009	41.61	411,371	958.95	4,470,066
1998 High	2.54	45,330,494	144,692,993	1,040.64	5,359,000	1,823,800	11,634,310	41.87	430,900	998.77	4,928,100
Predicted High	2.82	46,993,617	157,639,434	1,078.82	5,838,498	1,833,462	12,146,353	42.09	449,865	1,036.73	5,388,633
Spring High (Pot.)	3.15	48,426,171	173,409,813	1,111.71	6,422,586	1,843,374	12,753,073	42.32	472,336	1,069.39	5,950,250
Upper Bound	7.00	55,657,142	376,264,888	1,277.71	13,935,738	1,897,835	19,982,419	43.57	740,090	1,234.14	13,195,648

Central (Estuarine) and South (Seadrift)

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	4,737,615	9,974,139	108.76	369,413	0	0	0.00	0	108.76	369,413
Neap Low (Pot.)	-2.05	6,292,989	17,403,700	144.47	644,582	0	0	0.00	0	144.47	644,582
Predicted Low	-1.64	8,503,233	20,337,285	195.21	753,233	0	0	0.00	0	195.21	753,233
1998 Low	-1.36	10,100,430	23,190,365	231.87	858,902	0	0	0.00	0	231.87	858,902
Neap High (Pot.)	2.25	47,714,320	127,004,857	1,095.37	4,703,884	0	0	0.00	0	1,095.37	4,703,884
1998 High	2.54	48,845,509	141,009,380	1,121.33	5,222,570	0	0	0.00	0	1,121.33	5,222,570
Predicted High	2.96	50,224,520	162,842,030	1,152.99	6,031,187	0	0	0.00	0	1,152.99	6,031,187
Spring High (Pot.)	3.15	50,670,133	171,432,030	1,163.22	6,349,335	0	0	0.00	0	1,163.22	6,349,335
Upper Bound	7.00	55,686,556	377,157,916	1,278.38	13,968,813	0	0	0.00	0	1,278.38	13,968,813

Central (Estuarine) and South (No Seadrift)

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	4,737,615	9,974,139	108.76	369,413	1,325,379	2,029,123	30.43	75,153	78.33	294,260
Neap Low (Pot.)	-2.05	6,292,989	17,403,700	144.47	644,582	1,463,307	3,984,538	33.59	147,575	110.87	497,006
Predicted Low	-1.47	9,380,851	22,120,412	215.35	819,275	1,518,220	4,849,199	34.85	179,600	180.50	639,675
1998 Low	-1.36	10,100,430	23,190,365	231.87	858,902	1,528,548	5,016,771	35.09	185,806	196.78	673,096
Neap High (Pot.)	2.25	47,714,320	127,004,857	1,095.37	4,703,884	1,812,485	11,107,009	41.61	411,371	1,053.76	4,292,513
1998 High	2.54	48,845,509	141,009,380	1,121.33	5,222,570	1,823,800	11,634,310	41.87	430,900	1,079.47	4,791,670
Predicted High	2.80	49,772,347	153,841,126	1,142.61	5,697,820	1,832,815	12,109,690	42.08	448,507	1,100.54	5,249,313
Spring High (Pot.)	3.15	50,670,133	171,432,030	1,163.22	6,349,335	1,843,374	12,753,073	42.32	472,336	1,120.90	5,876,999
Upper Bound	7.00	55,686,556	377,157,916	1,278.38	13,968,813	1,897,835	19,982,419	43.57	740,090	1,234.81	13,228,723

Central (Riparian) and South (Seadrift)

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	4,737,089	9,973,351	108.75	369,383	0	0	0.00	0	108.75	369,383
Neap Low (Pot.)	-2.05	6,292,992	17,402,834	144.47	644,549	0	0	0.00	0	144.47	644,549
Predicted Low	-1.64	8,619,778	20,593,255	197.88	762,713	0	0	0.00	0	197.88	762,713
1998 Low	-1.36	10,098,560	23,189,207	231.83	858,860	0	0	0.00	0	231.83	858,860
Neap High (Pot.)	2.25	47,632,875	126,915,111	1,093.50	4,700,560	0	0	0.00	0	1,093.50	4,700,560
1998 High	2.54	48,716,908	140,889,125	1,118.38	5,218,116	0	0	0.00	0	1,118.38	5,218,116
Predicted High	2.95	49,967,098	161,149,812	1,147.08	5,968,512	0	0	0.00	0	1,147.08	5,968,512
Spring High (Pot.)	3.15	50,465,514	171,205,232	1,158.52	6,340,935	0	0	0.00	0	1,158.52	6,340,935
Upper Bound	7.00	55,679,983	376,395,775	1,278.23	13,940,585	0	0	0.00	0	1,278.23	13,940,585

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Central (Riparian) and South (No Seadrift)

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	4,737,089	9,973,351	108.75	369,383	1,325,379	2,029,123	30.43	75,153	78.32	294,231
Neap Low (Pot.)	-2.05	6,292,992	17,402,834	144.47	644,549	1,463,307	3,984,538	33.59	147,575	110.87	496,974
Predicted Low	-1.41	9,436,035	22,213,542	216.62	822,724	1,519,160	4,864,386	34.87	180,162	181.75	642,561
1998 Low	-1.36	10,098,560	23,189,207	231.83	858,860	1,528,548	5,016,771	35.09	185,806	196.74	673,053
Neap High (Pot.)	2.25	47,632,875	126,915,111	1,093.50	4,700,560	1,812,485	11,107,009	41.61	411,371	1,051.89	4,289,189
1998 High	2.54	48,716,908	140,889,125	1,118.38	5,218,116	1,823,800	11,634,310	41.87	430,900	1,076.51	4,787,216
Predicted High	2.79	49,576,316	153,186,131	1,138.11	5,673,561	1,832,488	12,091,364	42.07	447,828	1,096.04	5,225,733
Spring High (Pot.)	3.15	50,465,514	171,205,232	1,158.52	6,340,935	1,843,374	12,753,073	42.32	472,336	1,116.21	5,868,599
Upper Bound	7.00	55,679,983	376,395,775	1,278.23	13,940,585	1,897,835	19,982,419	43.57	740,090	1,234.66	13,200,496

North

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	5,590,999	9,578,018	128.35	354,741	1,055,177	1,336,895	24.22	49,515	104.13	305,227
Neap Low (Pot.)	-2.05	10,229,193	20,715,493	234.83	767,241	1,345,126	3,050,507	30.88	112,982	203.95	654,259
Predicted Low	-1.45	13,622,001	27,780,356	312.72	1,028,902	1,427,979	3,882,771	32.78	143,806	279.94	885,096
1998 Low	-1.36	13,967,840	29,021,528	320.66	1,074,871	1,439,542	4,011,810	33.05	148,586	287.61	926,286
Neap High (Pot.)	2.25	43,417,586	127,559,257	996.73	4,724,417	1,802,290	9,951,169	41.37	368,562	955.35	4,355,855
1998 High	2.54	45,171,594	140,406,533	1,036.99	5,200,242	1,815,280	10,475,771	41.67	387,992	995.32	4,812,251
Predicted High	2.78	46,647,316	151,439,266	1,070.87	5,608,862	1,824,608	10,912,579	41.89	404,170	1,028.98	5,204,693
Spring High (Pot.)	3.15	48,270,415	169,028,373	1,108.13	6,260,311	1,836,934	11,590,037	42.17	429,261	1,065.96	5,831,050
Upper Bound	7.00	55,604,498	371,310,634	1,276.50	13,752,247	1,893,887	18,799,259	43.48	696,269	1,233.02	13,055,978

Central (Estuarine)

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	3,823,051	8,931,928	87.76	330,812	1,055,177	1,336,895	24.22	49,515	63.54	281,298
Neap Low (Pot.)	-2.05	5,482,519	15,163,971	125.86	561,629	1,345,126	3,050,507	30.88	112,982	94.98	448,647
Predicted Low	-1.42	8,920,507	19,851,836	204.79	735,253	1,431,841	3,925,668	32.87	145,395	171.92	589,858
1998 Low	-1.36	9,350,292	20,399,991	214.65	755,555	1,439,542	4,011,810	33.05	148,586	181.61	606,970
Neap High (Pot.)	2.25	47,547,482	122,765,513	1,091.54	4,546,871	1,802,290	9,951,169	41.37	368,562	1,050.16	4,178,309
1998 High	2.54	48,686,649	136,723,115	1,117.69	5,063,819	1,815,280	10,475,771	41.67	387,992	1,076.01	4,675,828
Predicted High	2.75	49,463,571	147,033,100	1,135.52	5,445,671	1,823,499	10,857,858	41.86	402,143	1,093.66	5,043,528
Spring High (Pot.)	3.15	50,514,419	167,050,804	1,159.65	6,187,067	1,836,934	11,590,037	42.17	429,261	1,117.48	5,757,807
Upper Bound	7.00	55,634,058	372,205,537	1,277.18	13,785,391	1,893,887	18,799,259	43.48	696,269	1,233.70	13,089,122

Central (Riparian)

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	3,823,051	8,931,928	87.76	330,812	1,055,177	1,336,895	24.22	49,515	63.54	281,298
Neap Low (Pot.)	-2.05	5,482,522	15,163,972	125.86	561,629	1,345,126	3,050,507	30.88	112,982	94.98	448,647
Predicted Low	-1.42	8,918,546	19,851,659	204.74	735,247	1,431,841	3,925,668	32.87	145,395	171.87	589,852
1998 Low	-1.36	9,348,421	20,399,700	214.61	755,544	1,439,542	4,011,810	33.05	148,586	181.56	606,959
Neap High (Pot.)	2.25	47,465,987	122,676,453	1,089.66	4,543,573	1,802,290	9,951,169	41.37	368,562	1,048.29	4,175,011
1998 High	2.54	45,951,248	127,756,917	105.40	472,478	1,815,280	10,475,771	41.67	387,992	63.73	84,487
Predicted High	2.75	49,301,186	146,882,999	1,131.79	5,440,111	1,823,499	10,857,858	41.86	402,143	1,089.93	5,037,969
Spring High (Pot.)	3.15	50,309,853	166,824,711	1,154.95	6,178,693	1,836,934	11,590,037	42.17	429,261	1,112.78	5,749,433
Upper Bound	7.00	55,627,463	371,443,038	1,277.03	13,757,151	1,893,887	18,799,259	43.48	696,269	1,233.55	13,060,882

South (Seadrift)

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	4,213,005	9,356,479	96.72	346,536	0	0	0.00	0	96.72	346,536
Neap Low (Pot.)	-2.05	5,713,810	16,015,603	131.17	593,171	0	0	0.00	0	131.17	593,171
Predicted Low	-1.41	8,290,766	20,509,373	190.33	759,606	0	0	0.00	0	190.33	759,606
1998 Low	-1.36	8,566,546	20,930,900	196.66	775,219	0	0	0.00	0	196.66	775,219
Neap High (Pot.)	2.25	43,544,798	112,790,834	999.65	4,177,439	0	0	0.00	0	999.65	4,177,439
1998 High	2.54	45,313,031	125,678,120	1,040.24	4,654,746	0	0	0.00	0	1,040.24	4,654,746
Predicted High	2.74	46,594,901	134,877,356	1,069.67	4,995,458	0	0	0.00	0	1,069.67	4,995,458
Spring High (Pot.)	3.15	48,421,045	154,388,379	1,111.59	5,718,089	0	0	0.00	0	1,111.59	5,718,089
Upper Bound	7.00	55,657,496	357,241,225	1,277.72	13,231,158	0	0	0.00	0	1,277.72	13,231,158

*Bolinas Lagoon Ecosystem Restoration Project
Technical Appendices: Engineering Appendix*

South (No Seadrift)

Tide Condition	Tide Elev. ft-NGVD	Bolinas Lagoon				Seadrift Lagoon				Actual or Total	
		Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area ft ²	Volume ft ³	Area acres	Volume yds ³	Area acres	Volume yds ³
Spring Low (Pot.)	-3.45	4,213,005	9,356,479	96.72	346,536	1,325,379	2,029,123	30.43	75,153	66.29	271,384
Neap Low (Pot.)	-2.05	5,713,810	16,015,603	131.17	593,171	1,463,307	3,984,538	33.59	147,575	97.58	445,595
Predicted Low	-1.34	8,675,329	21,103,321	199.16	781,605	1,537,910	5,170,095	35.31	191,485	163.85	590,120
1998 Low	-1.36	8,566,546	20,930,900	196.66	775,219	1,528,548	5,016,771	35.09	185,806	161.57	589,412
Neap High (Pot.)	2.25	43,544,798	112,790,834	999.65	4,177,439	1,812,485	11,107,009	41.61	411,371	958.04	3,766,068
1998 High	2.54	45,313,031	125,678,120	1,040.24	4,654,746	1,823,800	11,634,310	41.87	430,900	998.37	4,223,845
Predicted High	2.58	45,595,931	127,496,235	1,046.73	4,722,083	1,825,244	11,707,291	41.90	433,603	1,004.83	4,288,480
Spring High (Pot.)	3.15	48,421,045	154,388,379	1,111.59	5,718,089	1,843,374	12,753,073	42.32	472,336	1,069.27	5,245,752
Upper Bound	7.00	55,657,496	357,241,225	1,277.72	13,231,158	1,897,835	19,982,419	43.57	740,090	1,234.15	12,491,068

APPENDIX 18
WITH PROJECT LAGOON VOLUMES AND TIDAL
PRISMS

With Project Lagoon Volumes and Tidal Prisms

North, Central (Estuarine), and South (Seadrift) Water Level

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	190.08	181.52	0.92	166.41
2018	183.83	175.55	0.89	155.37
2028	177.89	169.88	0.85	145.23
2038	172.26	164.51	0.83	135.94
2048	166.95	159.44	0.80	127.45
2058	161.95	154.66	0.77	119.70

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	145.64	129.91	0.86	112.13
2018	139.38	124.33	0.85	105.07
2028	133.45	119.03	0.83	98.56
2038	127.82	114.02	0.81	92.55
2048	122.51	109.28	0.80	87.03
2058	117.51	104.82	0.78	81.96

North, Central (Estuarine), and South (No Seadrift) Water Level

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	177.32	169.34	0.85	144.28
2018	171.07	163.37	0.82	134.01
2028	165.13	157.70	0.79	124.61
2038	159.51	152.33	0.76	116.01
2048	154.20	147.26	0.73	108.18
2058	149.20	142.48	0.71	101.06

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	134.53	120.00	0.83	99.73
2018	128.28	114.42	0.81	93.03
2028	122.34	109.13	0.80	86.85
2038	116.71	104.11	0.78	81.17
2048	111.40	99.37	0.76	75.95
2058	106.40	94.91	0.75	71.17

North, Central (Riparian), and South (Seadrift)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	189.85	181.31	0.92	166.00
2018	183.60	175.34	0.88	154.98
2028	177.66	169.67	0.85	144.85
2038	172.04	164.30	0.83	135.57
2048	166.72	159.22	0.80	127.09
2058	161.72	154.45	0.77	119.36

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	145.55	129.83	0.86	112.03
2018	139.30	124.25	0.84	104.97
2028	133.36	118.96	0.83	98.46
2038	127.73	113.94	0.81	92.46
2048	122.42	109.20	0.80	86.94
2058	117.42	104.74	0.78	81.87

North, Central (Riparian), and South (No Seadrift)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	177.10	169.13	0.85	143.91
2018	170.85	163.16	0.82	133.65
2028	164.91	157.49	0.79	124.26
2038	159.28	152.12	0.76	115.68
2048	153.97	147.04	0.73	107.85
2058	148.97	142.27	0.71	100.74

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	134.44	119.92	0.83	99.63
2018	128.19	114.35	0.81	92.94
2028	122.25	109.05	0.80	86.76
2038	116.63	104.03	0.78	81.08
2048	111.31	99.29	0.76	75.87
2058	106.31	94.83	0.75	71.09

North and Central (Estuarine)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	174.11	166.27	0.84	138.95
2018	167.85	160.30	0.80	128.87
2028	161.92	154.63	0.77	119.66
2038	156.29	149.26	0.75	111.24
2048	150.98	144.18	0.72	103.57
2058	145.98	139.41	0.69	96.60

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	131.45	117.25	0.82	96.40
2018	125.19	111.67	0.80	89.80
2028	119.26	106.38	0.79	83.72
2038	113.63	101.36	0.77	78.12
2048	108.32	96.62	0.76	72.99
2058	103.32	92.16	0.74	68.29

North and Central (Riparian)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	173.88	166.06	0.83	138.58
2018	167.63	160.09	0.80	128.52
2028	161.69	154.42	0.77	119.31
2038	156.07	149.04	0.74	110.91
2048	150.75	143.97	0.72	103.25
2058	145.75	139.19	0.69	96.29

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	131.36	117.17	0.82	96.30
2018	125.11	111.59	0.80	89.71
2028	119.17	106.30	0.79	83.63
2038	113.54	101.28	0.77	78.04
2048	108.23	96.54	0.76	72.90
2058	103.23	92.08	0.74	68.21

North and South (Seadrift)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	173.41	165.61	0.83	137.81
2018	167.16	159.64	0.80	127.78
2028	161.22	153.97	0.77	118.60
2038	155.60	148.59	0.74	110.22
2048	150.28	143.52	0.71	102.58
2058	145.28	138.75	0.69	95.65

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	131.80	117.56	0.82	96.78
2018	125.55	111.99	0.81	90.17
2028	119.61	106.69	0.79	84.07
2038	113.99	101.67	0.77	78.47
2048	108.67	96.94	0.76	73.33
2058	103.67	92.48	0.74	68.62

North and South (No Seadrift)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft	million ft	% of Pot.	million ft
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	160.66	153.43	0.77	117.74
2018	154.41	147.46	0.74	108.48
2028	148.47	141.79	0.71	100.04
2038	142.84	136.42	0.68	92.35
2048	137.53	131.34	0.65	85.38
2058	132.53	126.57	0.62	79.06

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft	million ft	% of Pot.	million ft
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	120.69	107.66	0.79	85.17
2018	114.44	102.08	0.77	78.92
2028	108.50	96.78	0.76	73.16
2038	102.88	91.77	0.74	67.88
2048	97.57	87.03	0.72	63.04
2058	92.57	82.57	0.71	58.62

Central (Estuarine) and South (Seadrift)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	171.43	163.72	0.82	134.59
2018	165.18	157.75	0.79	124.68
2028	159.24	152.08	0.76	115.62
2038	153.62	146.71	0.73	107.34
2048	148.31	141.63	0.70	99.81
2058	143.31	136.86	0.68	92.97

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	127.00	113.29	0.81	91.69
2018	120.75	107.71	0.79	85.23
2028	114.82	102.42	0.77	79.29
2038	109.19	97.40	0.76	73.82
2048	103.88	92.66	0.74	68.81
2058	98.88	88.20	0.73	64.22

Central (Estuarine) and South (No Seadrift)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	158.68	151.54	0.76	114.77
2018	152.43	145.57	0.73	105.63
2028	146.49	139.90	0.70	97.30
2038	140.87	134.53	0.67	89.72
2048	135.55	129.45	0.64	82.85
2058	130.55	124.68	0.61	76.63

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	115.90	103.38	0.78	80.36
2018	109.65	97.81	0.76	74.26
2028	103.71	92.51	0.74	68.65
2038	98.08	87.49	0.73	63.51
2048	92.77	82.75	0.71	58.80
2058	87.77	78.29	0.70	54.50

Central (Riparian) and South (Seadrift)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	171.21	163.50	0.82	134.23
2018	164.95	157.53	0.79	124.33
2028	159.02	151.86	0.76	115.28
2038	153.39	146.49	0.73	107.02
2048	148.08	141.42	0.70	99.50
2058	143.08	136.64	0.68	92.67

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	126.92	113.21	0.81	91.60
2018	120.66	107.63	0.79	85.14
2028	114.73	102.34	0.77	79.20
2038	109.10	97.32	0.76	73.74
2048	103.79	92.58	0.74	68.73
2058	98.79	88.12	0.73	64.14

Central (Riparian) and South (No Seadrift)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	158.45	151.32	0.76	114.43
2018	152.20	145.35	0.72	105.31
2028	146.26	139.68	0.69	96.99
2038	140.64	134.31	0.67	89.42
2048	135.33	129.24	0.64	82.56
2058	130.33	124.46	0.61	76.35

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	115.81	103.30	0.78	80.27
2018	109.56	97.73	0.76	74.17
2028	103.62	92.43	0.74	68.57
2038	97.99	87.41	0.73	63.43
2048	92.68	82.67	0.71	58.72
2058	87.68	78.21	0.70	54.42

North

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	157.44	150.35	0.75	112.93
2018	151.19	144.38	0.72	103.86
2028	145.25	138.71	0.69	95.60
2038	139.62	133.34	0.66	88.09
2048	134.31	128.27	0.63	81.28
2058	129.31	123.49	0.61	75.12

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	117.61	104.91	0.78	82.06
2018	111.36	99.33	0.76	75.91
2028	105.42	94.03	0.75	70.25
2038	99.79	89.02	0.73	65.05
2048	94.48	84.28	0.72	60.30
2058	89.48	79.82	0.70	55.96

Central (Estuarine)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	155.46	148.47	0.74	110.02
2018	149.21	142.50	0.71	101.07
2028	143.27	136.83	0.68	92.93
2038	137.65	131.45	0.65	85.53
2048	132.33	126.38	0.62	78.82
2058	127.33	121.60	0.60	72.75

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	112.81	100.63	0.77	77.32
2018	106.56	95.05	0.75	71.32
2028	100.63	89.76	0.73	65.81
2038	95.00	84.74	0.72	60.76
2048	89.69	80.00	0.70	56.13
2058	84.69	75.54	0.69	51.91

Central (Riparian)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	155.23	148.25	0.74	109.69
2018	148.98	142.28	0.71	100.76
2028	143.05	136.61	0.68	92.63
2038	137.42	131.24	0.65	85.24
2048	132.11	126.16	0.62	78.54
2058	127.11	121.39	0.60	72.49

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	112.73	100.55	0.77	77.24
2018	106.47	94.98	0.75	71.24
2028	100.54	89.68	0.73	65.73
2038	94.91	84.66	0.72	60.68
2048	89.60	79.92	0.70	56.06
2058	84.60	75.46	0.69	51.84

South (Seadrift)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	154.39	147.44	0.74	108.46
2018	148.14	141.47	0.70	99.58
2028	142.20	135.80	0.67	91.49
2038	136.57	130.43	0.65	84.15
2048	131.26	125.36	0.62	77.50
2058	126.26	120.58	0.59	71.48

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume	Potential	Effective %	Effective
	million ft ³	million ft ³	% of Pot.	million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	112.79	100.61	0.77	77.30
2018	106.54	95.03	0.75	71.30
2028	100.60	89.74	0.73	65.79
2038	94.98	84.72	0.72	60.74
2048	89.66	79.98	0.70	56.11
2058	84.66	75.52	0.69	51.89

South (No Seadrift)

Spring Tide (max. ocean elev. = 3.15 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	175.23	167.28	0.84	140.75
1978	152.17	145.65	0.72	105.50
1988	145.55	135.54	0.69	93.62
1998	138.42	131.44	0.65	86.03
2008	141.64	135.26	0.67	90.74
2018	135.38	129.29	0.64	82.64
2028	129.45	123.62	0.61	75.29
2038	123.82	118.25	0.58	68.64
2048	118.51	113.18	0.55	62.64
2058	113.51	108.40	0.53	57.25

Neap Tide (max. Ocean elev. = 2.25 NGVD)

Year	Volume million ft ³	Potential million ft ³	Effective % % of Pot.	Effective million ft ³
1968	133.29	118.84	0.83	98.34
1978	112.08	101.09	0.77	77.46
1988	107.20	92.16	0.75	69.32
1998	98.60	87.87	0.73	63.92
2008	101.68	90.70	0.74	66.78
2018	95.43	85.13	0.72	61.14
2028	89.50	79.83	0.70	55.97
2038	83.87	74.81	0.68	51.23
2048	78.56	70.07	0.67	46.91
2058	73.56	65.61	0.66	42.98

APPENDIX 19
WITH PROJECT WATER SURFACE ELEVATIONS

Change In Predicted Water Surface Elevations Resulting From Each Alternative				
Alternatives	Spring High Tide ft	Spring Low Tide ft	Neap High Tide ft	Neap Low Tide ft
1968 Water Level	3.00	-1.70	2.08	-1.11
1978 Water Level	2.71	-1.38	1.92	-1.26
1988 Water Level	2.63	-1.28	1.88	-1.30
1998 Water Level	2.54	-1.18	1.81	-1.36
North	2.78	-1.45	1.96	-1.22
Central (Estuarine)	2.75	-1.42	1.92	-1.26
Central (modified)	2.75	-1.42	1.92	-1.26
South (Seadrift)	2.74	-1.41	1.92	-1.26
South (No Seadrift)	2.58	-1.23	1.84	-1.34
North and Central (Estuarine)	2.99	-1.68	2.06	-1.12
North and Central (Riparian)	2.99	-1.68	2.06	-1.12
North and South (Seadrift)	2.98	-1.67	2.07	-1.12
North and South (No Seadrift)	2.82	-1.49	1.98	-1.20
Central (Estuarine) and South (Seadrift)	2.96	-1.64	2.03	-1.15
Central (Estuarine) and South (No Seadrift)	2.80	-1.47	1.95	-1.23
Central (Riparian) and South (Seadrift)	2.95	-1.64	2.03	-1.16
Central (Riparian) and South (No Seadrift)	2.79	-1.46	1.94	-1.24
North, Central (Estuarine), and South (Seadrift)	3.15	-1.91	2.17	-1.02
North, Central (Estuarine), and South (No Seadrift)	3.03	-1.73	2.09	-1.10
North, Central (Riparian), and South (Seadrift)	3.15	-1.90	2.17	-1.02
North, Central (Riparian), and South (No Seadrift)	3.03	-1.72	2.09	-1.10

Water Surface Elevations With Project

Without Project Condition

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	131.85	3.15	-3.45	0.78	0.32	2.46	-1.09	3.55
2018	125.60	3.15	-3.45	0.75	0.29	2.38	-1.01	3.38
2028	119.67	3.15	-3.45	0.73	0.27	2.30	-0.92	3.22
2038	114.04	3.15	-3.45	0.71	0.24	2.23	-0.84	3.07
2048	108.73	3.15	-3.45	0.69	0.22	2.16	-0.77	2.93
2058	103.73	3.15	-3.45	0.67	0.20	2.10	-0.70	2.80

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.86	0.62	1.93	-1.26	3.19
1988	107.20	2.25	-2.05	0.84	0.63	1.90	-1.30	3.19
1998	98.60	2.25	-2.05	0.82	0.66	1.84	-1.36	3.20
2008	92.04	2.25	-2.05	0.80	0.69	1.79	-1.41	3.20
2018	85.79	2.25	-2.05	0.78	0.71	1.75	-1.45	3.20
2028	79.85	2.25	-2.05	0.76	0.73	1.70	-1.49	3.20
2038	74.22	2.25	-2.05	0.74	0.75	1.67	-1.53	3.20
2048	68.91	2.25	-2.05	0.72	0.77	1.63	-1.57	3.20
2058	63.91	2.25	-2.05	0.71	0.78	1.59	-1.61	3.20

North, Central (Estuarine), and South (Seadrift) Water Level

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	190.08	3.15	-3.45	1.00	0.55	3.15	-1.91	5.06
2018	183.83	3.15	-3.45	0.99	0.53	3.11	-1.82	4.93
2028	177.89	3.15	-3.45	0.96	0.50	3.04	-1.74	4.77
2038	172.26	3.15	-3.45	0.94	0.48	2.97	-1.66	4.62
2048	166.95	3.15	-3.45	0.92	0.46	2.90	-1.58	4.48
2058	161.95	3.15	-3.45	0.90	0.44	2.84	-1.51	4.35

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	145.64	2.25	-2.05	0.97	0.50	2.17	-1.02	3.19
2018	139.38	2.25	-2.05	0.94	0.52	2.12	-1.07	3.19
2028	133.45	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
2038	127.82	2.25	-2.05	0.91	0.56	2.04	-1.15	3.19
2048	122.51	2.25	-2.05	0.89	0.58	2.00	-1.19	3.18
2058	117.51	2.25	-2.05	0.87	0.60	1.96	-1.22	3.18

North, Central (Estuarine), and South (No Seadrift) Water Level

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	177.32	3.15	-3.45	0.96	0.50	3.03	-1.73	4.76
2018	171.07	3.15	-3.45	0.94	0.48	2.95	-1.64	4.59
2028	165.13	3.15	-3.45	0.91	0.45	2.88	-1.56	4.43
2038	159.51	3.15	-3.45	0.89	0.43	2.81	-1.48	4.28
2048	154.20	3.15	-3.45	0.87	0.41	2.74	-1.40	4.14
2058	149.20	3.15	-3.45	0.85	0.39	2.67	-1.33	4.01

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	134.53	2.25	-2.05	0.93	0.54	2.09	-1.10	3.19
2018	128.28	2.25	-2.05	0.91	0.56	2.04	-1.15	3.19
2028	122.34	2.25	-2.05	0.89	0.58	1.99	-1.19	3.18
2038	116.71	2.25	-2.05	0.87	0.60	1.95	-1.23	3.18
2048	111.40	2.25	-2.05	0.85	0.62	1.91	-1.27	3.18
2058	106.40	2.25	-2.05	0.83	0.64	1.87	-1.30	3.18

North, Central (Riparian), and South (Seadrift)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	189.85	3.15	-3.45	1.00	0.55	3.15	-1.90	5.05
2018	183.60	3.15	-3.45	0.99	0.53	3.11	-1.81	4.93
2028	177.66	3.15	-3.45	0.96	0.50	3.04	-1.73	4.77
2038	172.04	3.15	-3.45	0.94	0.48	2.96	-1.65	4.62
2048	166.72	3.15	-3.45	0.92	0.46	2.90	-1.58	4.48
2058	161.72	3.15	-3.45	0.90	0.44	2.83	-1.51	4.34

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	145.55	2.25	-2.05	0.97	0.50	2.17	-1.02	3.19
2018	139.30	2.25	-2.05	0.94	0.52	2.12	-1.07	3.19
2028	133.36	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
2038	127.73	2.25	-2.05	0.90	0.56	2.04	-1.15	3.19
2048	122.42	2.25	-2.05	0.89	0.58	2.00	-1.19	3.18
2058	117.42	2.25	-2.05	0.87	0.60	1.96	-1.22	3.18

North, Central (Riparian), and South (No Seadrift)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	177.10	3.15	-3.45	0.96	0.50	3.03	-1.72	4.75
2018	170.85	3.15	-3.45	0.94	0.47	2.95	-1.64	4.59
2028	164.91	3.15	-3.45	0.91	0.45	2.87	-1.55	4.43
2038	159.28	3.15	-3.45	0.89	0.43	2.80	-1.48	4.28
2048	153.97	3.15	-3.45	0.87	0.41	2.74	-1.40	4.14
2058	148.97	3.15	-3.45	0.85	0.39	2.67	-1.33	4.00

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	134.44	2.25	-2.05	0.93	0.54	2.09	-1.10	3.19
2018	128.19	2.25	-2.05	0.91	0.56	2.04	-1.15	3.19
2028	122.25	2.25	-2.05	0.89	0.58	1.99	-1.19	3.18
2038	116.63	2.25	-2.05	0.87	0.60	1.95	-1.23	3.18
2048	111.31	2.25	-2.05	0.85	0.62	1.91	-1.27	3.18
2058	106.31	2.25	-2.05	0.83	0.64	1.87	-1.30	3.18

Central (Estuarine) and South (Seadrift)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	171.43	3.15	-3.45	0.94	0.48	2.96	-1.64	4.60
2018	165.18	3.15	-3.45	0.91	0.45	2.88	-1.56	4.44
2028	159.24	3.15	-3.45	0.89	0.43	2.80	-1.47	4.28
2038	153.62	3.15	-3.45	0.87	0.40	2.73	-1.40	4.13
2048	148.31	3.15	-3.45	0.85	0.38	2.66	-1.32	3.99
2058	143.31	3.15	-3.45	0.83	0.36	2.60	-1.25	3.85

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	127.00	2.25	-2.05	0.90	0.56	2.03	-1.15	3.18
2018	120.75	2.25	-2.05	0.88	0.59	1.98	-1.20	3.18
2028	114.82	2.25	-2.05	0.86	0.61	1.94	-1.24	3.18
2038	109.19	2.25	-2.05	0.84	0.63	1.89	-1.28	3.18
2048	103.88	2.25	-2.05	0.82	0.64	1.85	-1.32	3.17
2058	98.88	2.25	-2.05	0.81	0.66	1.82	-1.36	3.17

Central (Estuarine) and South (No Seadrift)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	158.68	3.15	-3.45	0.89	0.43	2.80	-1.47	4.26
2018	152.43	3.15	-3.45	0.86	0.40	2.72	-1.38	4.10
2028	146.49	3.15	-3.45	0.84	0.38	2.64	-1.30	3.94
2038	140.87	3.15	-3.45	0.82	0.35	2.57	-1.22	3.79
2048	135.55	3.15	-3.45	0.79	0.33	2.50	-1.14	3.65
2058	130.55	3.15	-3.45	0.77	0.31	2.44	-1.07	3.51

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	115.90	2.25	-2.05	0.86	0.60	1.95	-1.23	3.18
2018	109.65	2.25	-2.05	0.84	0.62	1.90	-1.28	3.18
2028	103.71	2.25	-2.05	0.82	0.65	1.85	-1.32	3.17
2038	98.08	2.25	-2.05	0.80	0.66	1.81	-1.36	3.17
2048	92.77	2.25	-2.05	0.79	0.68	1.77	-1.40	3.17
2058	87.77	2.25	-2.05	0.77	0.70	1.73	-1.44	3.17

Central (Riparian) and South (Seadrift)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	171.21	3.15	-3.45	0.94	0.48	2.95	-1.64	4.60
2018	164.95	3.15	-3.45	0.91	0.45	2.87	-1.55	4.43
2028	159.02	3.15	-3.45	0.89	0.43	2.80	-1.47	4.27
2038	153.39	3.15	-3.45	0.87	0.40	2.73	-1.39	4.12
2048	148.08	3.15	-3.45	0.84	0.38	2.66	-1.32	3.98
2058	143.08	3.15	-3.45	0.82	0.36	2.60	-1.25	3.85

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	126.92	2.25	-2.05	0.90	0.56	2.03	-1.16	3.18
2018	120.66	2.25	-2.05	0.88	0.59	1.98	-1.20	3.18
2028	114.73	2.25	-2.05	0.86	0.61	1.94	-1.24	3.18
2038	109.10	2.25	-2.05	0.84	0.63	1.89	-1.28	3.18
2048	103.79	2.25	-2.05	0.82	0.64	1.85	-1.32	3.17
2058	98.79	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17

Central (Riparian) and South (No Seadrift)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	158.45	3.15	-3.45	0.89	0.42	2.79	-1.46	4.26
2018	152.20	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
2028	146.26	3.15	-3.45	0.84	0.37	2.64	-1.29	3.93
2038	140.64	3.15	-3.45	0.81	0.35	2.57	-1.21	3.78
2048	135.33	3.15	-3.45	0.79	0.33	2.50	-1.14	3.64
2058	130.33	3.15	-3.45	0.77	0.31	2.44	-1.07	3.51

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	115.81	2.25	-2.05	0.86	0.60	1.94	-1.24	3.18
2018	109.56	2.25	-2.05	0.84	0.62	1.90	-1.28	3.18
2028	103.62	2.25	-2.05	0.82	0.65	1.85	-1.32	3.17
2038	97.99	2.25	-2.05	0.80	0.67	1.81	-1.36	3.17
2048	92.68	2.25	-2.05	0.79	0.68	1.77	-1.40	3.17
2058	87.68	2.25	-2.05	0.77	0.70	1.73	-1.44	3.17

North and South (Seadrift)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	173.41	3.15	-3.45	0.95	0.48	2.98	-1.67	4.65
2018	167.16	3.15	-3.45	0.92	0.46	2.90	-1.59	4.49
2028	161.22	3.15	-3.45	0.90	0.44	2.83	-1.50	4.33
2038	155.60	3.15	-3.45	0.87	0.41	2.76	-1.42	4.18
2048	150.28	3.15	-3.45	0.85	0.39	2.69	-1.35	4.04
2058	145.28	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	131.80	2.25	-2.05	0.92	0.55	2.07	-1.12	3.19
2018	125.55	2.25	-2.05	0.90	0.57	2.02	-1.17	3.18
2028	119.61	2.25	-2.05	0.88	0.59	1.97	-1.21	3.18
2038	113.99	2.25	-2.05	0.86	0.61	1.93	-1.25	3.18
2048	108.67	2.25	-2.05	0.84	0.63	1.89	-1.29	3.18
2058	103.67	2.25	-2.05	0.82	0.65	1.85	-1.32	3.17

North and South (No Seadrift)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	160.66	3.15	-3.45	0.90	0.43	2.82	-1.49	4.31
2018	154.41	3.15	-3.45	0.87	0.41	2.74	-1.41	4.15
2028	148.47	3.15	-3.45	0.85	0.38	2.67	-1.32	3.99
2038	142.84	3.15	-3.45	0.82	0.36	2.59	-1.25	3.84
2048	137.53	3.15	-3.45	0.80	0.34	2.53	-1.17	3.70
2058	132.53	3.15	-3.45	0.78	0.32	2.46	-1.10	3.57

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	120.69	2.25	-2.05	0.88	0.59	1.98	-1.20	3.18
2018	114.44	2.25	-2.05	0.86	0.61	1.93	-1.25	3.18
2028	108.50	2.25	-2.05	0.84	0.63	1.89	-1.29	3.18
2038	102.88	2.25	-2.05	0.82	0.65	1.85	-1.33	3.17
2048	97.57	2.25	-2.05	0.80	0.67	1.81	-1.37	3.17
2058	92.57	2.25	-2.05	0.79	0.68	1.77	-1.40	3.17

North and Central (Estuarine)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	174.11	3.15	-3.45	0.95	0.49	2.99	-1.68	4.67
2018	167.85	3.15	-3.45	0.92	0.46	2.91	-1.59	4.51
2028	161.92	3.15	-3.45	0.90	0.44	2.84	-1.51	4.35
2038	156.29	3.15	-3.45	0.88	0.42	2.76	-1.43	4.20
2048	150.98	3.15	-3.45	0.86	0.39	2.70	-1.36	4.06
2058	145.98	3.15	-3.45	0.84	0.37	2.63	-1.29	3.92

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	131.45	2.25	-2.05	0.92	0.55	2.06	-1.12	3.19
2018	125.19	2.25	-2.05	0.90	0.57	2.02	-1.17	3.18
2028	119.26	2.25	-2.05	0.88	0.59	1.97	-1.21	3.18
2038	113.63	2.25	-2.05	0.86	0.61	1.93	-1.25	3.18
2048	108.32	2.25	-2.05	0.84	0.63	1.89	-1.29	3.18
2058	103.32	2.25	-2.05	0.82	0.65	1.85	-1.33	3.17

North and Central (Riparian)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	173.88	3.15	-3.45	0.95	0.49	2.99	-1.68	4.67
2018	167.63	3.15	-3.45	0.92	0.46	2.91	-1.59	4.50
2028	161.69	3.15	-3.45	0.90	0.44	2.83	-1.51	4.34
2038	156.07	3.15	-3.45	0.88	0.41	2.76	-1.43	4.19
2048	150.75	3.15	-3.45	0.86	0.39	2.69	-1.36	4.05
2058	145.75	3.15	-3.45	0.84	0.37	2.63	-1.29	3.92

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	131.36	2.25	-2.05	0.92	0.55	2.06	-1.12	3.19
2018	125.11	2.25	-2.05	0.90	0.57	2.02	-1.17	3.18
2028	119.17	2.25	-2.05	0.88	0.59	1.97	-1.21	3.18
2038	113.54	2.25	-2.05	0.86	0.61	1.93	-1.25	3.18
2048	108.23	2.25	-2.05	0.84	0.63	1.89	-1.29	3.18
2058	103.23	2.25	-2.05	0.82	0.65	1.85	-1.33	3.17

North

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	157.44	3.15	-3.45	0.88	0.42	2.78	-1.45	4.23
2018	151.19	3.15	-3.45	0.86	0.39	2.70	-1.36	4.06
2028	145.25	3.15	-3.45	0.83	0.37	2.62	-1.28	3.90
2038	139.62	3.15	-3.45	0.81	0.35	2.55	-1.20	3.75
2048	134.31	3.15	-3.45	0.79	0.33	2.49	-1.13	3.61
2058	129.31	3.15	-3.45	0.77	0.31	2.42	-1.06	3.48

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	117.61	2.25	-2.05	0.87	0.60	1.96	-1.22	3.18
2018	111.36	2.25	-2.05	0.85	0.62	1.91	-1.27	3.18
2028	105.42	2.25	-2.05	0.83	0.64	1.87	-1.31	3.18
2038	99.79	2.25	-2.05	0.81	0.66	1.82	-1.35	3.17
2048	94.48	2.25	-2.05	0.79	0.68	1.78	-1.39	3.17
2058	89.48	2.25	-2.05	0.77	0.70	1.74	-1.42	3.17

Central (Estuarine)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	155.46	3.15	-3.45	0.87	0.41	2.75	-1.42	4.18
2018	149.21	3.15	-3.45	0.85	0.39	2.68	-1.33	4.01
2028	143.27	3.15	-3.45	0.83	0.36	2.60	-1.25	3.85
2038	137.65	3.15	-3.45	0.80	0.34	2.53	-1.17	3.70
2048	132.33	3.15	-3.45	0.78	0.32	2.46	-1.10	3.56
2058	127.33	3.15	-3.45	0.76	0.30	2.40	-1.03	3.43

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	112.81	2.25	-2.05	0.85	0.61	1.92	-1.26	3.18
2018	106.56	2.25	-2.05	0.83	0.64	1.87	-1.30	3.18
2028	100.63	2.25	-2.05	0.81	0.66	1.83	-1.34	3.17
2038	95.00	2.25	-2.05	0.79	0.68	1.79	-1.39	3.17
2048	89.69	2.25	-2.05	0.78	0.69	1.74	-1.42	3.17
2058	84.69	2.25	-2.05	0.76	0.71	1.71	-1.46	3.17

Central (Riparian)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	155.23	3.15	-3.45	0.87	0.41	2.75	-1.42	4.17
2018	148.98	3.15	-3.45	0.85	0.39	2.67	-1.33	4.00
2028	143.05	3.15	-3.45	0.82	0.36	2.60	-1.25	3.85
2038	137.42	3.15	-3.45	0.80	0.34	2.53	-1.17	3.70
2048	132.11	3.15	-3.45	0.78	0.32	2.46	-1.10	3.55
2058	127.11	3.15	-3.45	0.76	0.30	2.39	-1.03	3.42

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	112.73	2.25	-2.05	0.85	0.61	1.92	-1.26	3.18
2018	106.47	2.25	-2.05	0.83	0.64	1.87	-1.30	3.18
2028	100.54	2.25	-2.05	0.81	0.66	1.83	-1.35	3.17
2038	94.91	2.25	-2.05	0.79	0.68	1.78	-1.39	3.17
2048	89.60	2.25	-2.05	0.78	0.69	1.74	-1.42	3.17
2058	84.60	2.25	-2.05	0.76	0.71	1.71	-1.46	3.17

South (Seadrift)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	154.39	3.15	-3.45	0.87	0.41	2.74	-1.41	4.15
2018	148.14	3.15	-3.45	0.84	0.38	2.66	-1.32	3.98
2028	142.20	3.15	-3.45	0.82	0.36	2.59	-1.24	3.82
2038	136.57	3.15	-3.45	0.80	0.34	2.51	-1.16	3.67
2048	131.26	3.15	-3.45	0.78	0.31	2.45	-1.08	3.53
2058	126.26	3.15	-3.45	0.76	0.29	2.38	-1.01	3.40

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	112.79	2.25	-2.05	0.85	0.61	1.92	-1.26	3.18
2018	106.54	2.25	-2.05	0.83	0.64	1.87	-1.30	3.18
2028	100.60	2.25	-2.05	0.81	0.66	1.83	-1.34	3.17
2038	94.98	2.25	-2.05	0.79	0.68	1.79	-1.39	3.17
2048	89.66	2.25	-2.05	0.78	0.69	1.74	-1.42	3.17
2058	84.66	2.25	-2.05	0.76	0.71	1.71	-1.46	3.17

South (No Seadrift)

Spring Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Spring High	Spring Low	Spring Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	175.23	3.15	-3.45	0.95	0.49	3.00	-1.70	4.70
1978	152.17	3.15	-3.45	0.86	0.40	2.71	-1.38	4.09
1988	145.55	3.15	-3.45	0.83	0.37	2.63	-1.28	3.91
1998	138.42	3.15	-3.45	0.81	0.34	2.54	-1.18	3.72
2008	141.64	3.15	-3.45	0.82	0.36	2.58	-1.23	3.81
2018	135.38	3.15	-3.45	0.79	0.33	2.50	-1.14	3.64
2028	129.45	3.15	-3.45	0.77	0.31	2.42	-1.06	3.48
2038	123.82	3.15	-3.45	0.75	0.28	2.35	-0.98	3.33
2048	118.51	3.15	-3.45	0.73	0.26	2.29	-0.91	3.19
2058	113.51	3.15	-3.45	0.71	0.24	2.22	-0.84	3.06

Neap Tide

Year	Lag. Vol.	Ocean H	Ocean L	Lag. High %	Lag. Low %	Neap High	Neap Low	Neap Range
	million ft ³	feet-NGVD	feet-NGVD			feet-NGVD	feet-NGVD	feet
1968	133.29	2.25	-2.05	0.92	0.54	2.08	-1.11	3.19
1978	112.08	2.25	-2.05	0.85	0.62	1.92	-1.26	3.18
1988	107.20	2.25	-2.05	0.83	0.63	1.88	-1.30	3.18
1998	98.60	2.25	-2.05	0.81	0.66	1.81	-1.36	3.17
2008	101.68	2.25	-2.05	0.82	0.65	1.84	-1.34	3.17
2018	95.43	2.25	-2.05	0.80	0.67	1.79	-1.38	3.17
2028	89.50	2.25	-2.05	0.77	0.70	1.74	-1.42	3.17
2038	83.87	2.25	-2.05	0.76	0.71	1.70	-1.47	3.17
2048	78.56	2.25	-2.05	0.74	0.73	1.66	-1.50	3.16
2058	73.56	2.25	-2.05	0.72	0.75	1.62	-1.54	3.16

APPENDIX 20
WITH PROJECT HABITAT LEVELS

Bolinas Lagoon Habitat Level Changes For Entire Lagoon Resulting From Each Alternative

(With Tidal Prism Induced Change In Water Surface Elevation)

*Seadrift Lagoon was counted as upland habitat for 1998 habitat calculations and for any alternative scenario that did not include the South alternative.

Defining Water Surface Elevations - Upland, Intertidal, and Subtidal

	Upper Bound Water Level		
	Upland	Intertidal	Subtidal
1968 Water Level	7.00	3.00	-1.70
1978 Water Level	7.00	2.71	-1.38
1988 Water Level	7.00	2.63	-1.30
1998 Water Level	7.00	2.54	-1.36
North	7.00	2.78	-1.45
Central (Estuarine)	7.00	2.75	-1.42
Central (modified)	7.00	2.75	-1.42
South (Seadrift)	7.00	2.74	-1.41
South (No Seadrift)	7.00	2.58	-1.34
North and Central (Estuarine)	7.00	2.99	-1.68
North and Central (Riparian)	7.00	2.99	-1.68
North and South (Seadrift)	7.00	2.98	-1.67
North and South (No Seadrift)	7.00	2.82	-1.49
Central (Estuarine) and South (Seadrift)	7.00	2.96	-1.64
Central (Estuarine) and South (No Seadrift)	7.00	2.80	-1.47
Central (Riparian) and South (Seadrift)	7.00	2.95	-1.64
Central (Riparian) and South (No Seadrift)	7.00	2.79	-1.46
North, Central (Estuarine), and South (Seadrift)	7.00	3.15	-1.91
North, Central (Estuarine), and South (No Seadrift)	7.00	3.03	-1.73
North, Central (Riparian), and South (Seadrift)	7.00	3.15	-1.90
North, Central (Riparian), and South (No Seadrift)	7.00	3.03	-1.72

Upland (no tidal contribution) Habitat

Alternative	1998 Levels		Constructed ¹		Change In Habitat	
	Surface Area	Volume ³	Surface Area	Volume ³	Surface Area	Volume ³
	acres	yds ³	acres	yds ³	acres	yds ³
North	238.10	8,243,436	204.04	7,851,285	-34.06	-392,150
Central (Estuarine)	238.10	8,243,436	140.04	8,045,595	-98.06	-197,841
Central (modified)	238.10	8,243,436	143.61	8,022,913	-94.49	-220,523
South (Seadrift)	238.10	8,243,436	208.05	8,235,700	-30.05	-7,736
South (No Seadrift)	238.10	8,243,436	229.31	8,202,588	-8.79	-40,848
North and Central (Estuarine)	238.10	8,243,436	125.64	7,619,159	-112.46	-624,277
North and Central (Riparian)	238.10	8,243,436	130.07	7,598,088	-108.03	-645,348
North and South (Seadrift)	238.10	8,243,436	179.78	7,816,253	-58.32	-427,183
North and South (No Seadrift)	238.10	8,243,436	197.41	7,807,015	-40.69	-436,421
Central (Estuarine) and South (Seadrift)	238.10	8,243,436	125.39	7,937,626	-112.71	-305,810
Central (Estuarine) and South (No Seadrift)	238.10	8,243,436	134.28	7,979,410	-103.82	-264,025
Central (Riparian) and South (Seadrift)	238.10	8,243,436	131.15	7,972,073	-106.95	-271,362
Central (Riparian) and South (No Seadrift)	238.10	8,243,436	138.62	7,974,763	-99.48	-268,673
North, Central (Estuarine), and South (Seadrift)	238.10	8,243,436	115.05	7,619,566	-123.05	-623,869
North, Central (Estuarine), and South (No Seadrift)	238.10	8,243,436	117.47	7,568,491	-120.63	-674,945
North, Central (Riparian), and South (Seadrift)	238.10	8,243,436	119.59	7,599,700	-118.51	-643,736
North, Central (Riparian), and South (No Seadrift)	238.10	8,243,436	121.97	7,547,720	-116.13	-695,715

Intertidal Habitat

Alternative	1998 Levels		Constructed ¹		Change In Habitat	
	Surface Area	Volume ³	Surface Area	Volume ³	Surface Area	Volume ³
	acres	yds ³	acres	yds ³	acres	yds ³
North	848.53	3,584,714	749.05	4,319,597	-99.48	734,883
Central (Estuarine)	848.53	3,584,714	921.75	4,453,670	73.22	868,956
Central (modified)	848.53	3,584,714	918.06	4,448,117	69.54	863,403
South (Seadrift)	848.53	3,584,714	879.34	4,235,852	30.81	651,138
South (No Seadrift)	848.53	3,584,714	840.98	3,698,360	-7.55	113,646
North and Central (Estuarine)	848.53	3,584,714	835.12	5,304,969	-13.41	1,720,255
North and Central (Riparian)	848.53	3,584,714	830.54	5,297,813	-17.99	1,713,100
North and South (Seadrift)	848.53	3,584,714	802.28	5,099,668	-46.24	1,514,954
North and South (No Seadrift)	848.53	3,584,714	744.03	4,458,622	-104.50	873,908
Central (Estuarine) and South (Seadrift)	848.53	3,584,714	957.79	5,277,954	109.26	1,693,240
Central (Estuarine) and South (No Seadrift)	848.53	3,584,714	920.04	4,609,638	71.51	1,024,924
Central (Riparian) and South (Seadrift)	848.53	3,584,714	949.20	5,205,799	100.67	1,621,085
Central (Riparian) and South (No Seadrift)	848.53	3,584,714	914.30	4,583,171	65.77	998,457
North, Central (Estuarine), and South (Seadrift)	848.53	3,584,714	862.34	6,074,382	13.82	2,489,668
North, Central (Estuarine), and South (No Seadrift)	848.53	3,584,714	832.87	5,460,468	-15.66	1,875,754
North, Central (Riparian), and South (Seadrift)	848.53	3,584,714	856.68	6,061,159	8.15	2,476,445
North, Central (Riparian), and South (No Seadrift)	848.53	3,584,714	827.31	5,448,416	-21.22	1,863,703

Subtidal Habitat

Alternative	1998 Levels		Constructed ¹		Change In Habitat	
	Surface Area	Volume ³	Surface Area	Volume ³	Surface Area	Volume ³
	acres	yds ³	acres	yds ³	acres	yds ³
North	146.39	523,318	279.94	885,096	133.54	361,778
Central (Estuarine)	146.39	523,318	171.92	589,858	25.52	66,540
Central (modified)	146.39	523,318	171.87	589,852	25.48	66,534
South (Seadrift)	146.39	523,318	190.33	759,606	43.94	236,289
South (No Seadrift)	146.39	523,318	163.85	590,120	17.46	66,802
North and Central (Estuarine)	146.39	523,318	272.94	855,584	126.55	332,266
North and Central (Riparian)	146.39	523,318	272.94	855,584	126.55	332,266
North and South (Seadrift)	146.39	523,318	295.64	1,019,817	149.25	496,499
North and South (No Seadrift)	146.39	523,318	292.70	930,011	146.31	406,693
Central (Estuarine) and South (Seadrift)	146.39	523,318	195.21	753,233	48.81	229,915
Central (Estuarine) and South (No Seadrift)	146.39	523,318	180.50	639,675	34.11	116,357
Central (Riparian) and South (Seadrift)	146.39	523,318	197.88	762,713	51.49	239,395
Central (Riparian) and South (No Seadrift)	146.39	523,318	181.75	642,561	35.35	119,243
North, Central (Estuarine), and South (Seadrift)	146.39	523,318	300.99	965,467	154.60	442,149
North, Central (Estuarine), and South (No Seadrift)	146.39	523,318	284.47	890,366	138.08	367,048
North, Central (Riparian), and South (Seadrift)	146.39	523,318	301.96	970,362	155.57	447,044
North, Central (Riparian), and South (No Seadrift)	146.39	523,318	285.39	894,995	139.00	371,677

APPENDIX 21

WITH PROJECT O'BRIEN INLET CLOSURE ANALYSIS

Inlet Closure Date Adjustment Due to Increased Potential Tidal Prism
 (Worst Case Scenario - Large Waves/No Run Off/Neap Tide)

Potential Closure has been estimated at a Closure Index of 15

Inlet Closure Index Summary

Alternative	Year				
	1998	2008	2018	2038	2058
Without Project	10.5	11.2	12.0	13.9	16.1
South (Seadrift)		9.5	9.7	10.9	12.2
South (No Seadrift)		10.3	10.8	12.3	14.0
Central (Estuarine)		9.1	9.7	10.9	12.2
Central (Riparian)		9.1	9.7	10.9	12.2
North		9.2	9.3	10.3	11.5
Central (Estuarine) and South (Seadrift)		8.4	8.5	9.4	10.4
Central (Estuarine) and South (No Seadrift)		9.0	9.4	10.5	11.7
Central (Riparian) and South (Seadrift)		8.4	8.5	9.5	10.4
Central (Riparian) and South (No Seadrift)		9.0	9.4	10.5	11.8
North and South (Seadrift)		8.5	8.2	9.0	9.9
North and South (No Seadrift)		9.0	9.0	10.0	11.1
North and Central (Estuarine)		8.2	8.2	9.1	10.0
North and Central (Riparian)		8.2	8.2	9.1	10.0
North, Central (Estuarine), and South (Seadrift)		7.6	7.4	8.1	8.8
North, Central (Estuarine), and South (No Seadrift)		8.1	8.0	8.8	9.7
North, Central (Riparian), and South (Seadrift)		7.6	7.4	8.1	8.8
North, Central (Riparian), and South (No Seadrift)		8.1	8.0	8.8	9.7

North, Central (Estuarine), and South (Seadrift) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	121.32	250	4.3	0	5,935	45,000	7.6
2018	124.33	250	4.3	0	6,083	45,000	7.4
2028	119.03	250	4.3	0	5,824	45,000	7.7
2038	114.02	250	4.3	0	5,578	45,000	8.1
2048	109.28	250	4.3	0	5,346	45,000	8.4
2058	104.82	250	4.3	0	5,128	45,000	8.8

North, Central (Estuarine), and South (No Seadrift) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	114.19	250	4.3	0	5,587	45,000	8.1
2018	114.42	250	4.3	0	5,598	45,000	8.0
2028	109.13	250	4.3	0	5,339	45,000	8.4
2038	104.11	250	4.3	0	5,093	45,000	8.8
2048	99.37	250	4.3	0	4,862	45,000	9.3
2058	94.91	250	4.3	0	4,643	45,000	9.7

North, Central (Riparian) and South (Seadrift) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	121.23	250	4.3	0	5,931	45,000	7.6
2018	124.25	250	4.3	0	6,079	45,000	7.4
2028	118.96	250	4.3	0	5,820	45,000	7.7
2038	113.94	250	4.3	0	5,574	45,000	8.1
2048	109.20	250	4.3	0	5,343	45,000	8.4
2058	104.74	250	4.3	0	5,124	45,000	8.8

North, Central (Riparian) and South (No Seadrift) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	114.11	250	4.3	0	5,583	45,000	8.1
2018	114.35	250	4.3	0	5,594	45,000	8.0
2028	109.05	250	4.3	0	5,335	45,000	8.4
2038	104.03	250	4.3	0	5,090	45,000	8.8
2048	99.29	250	4.3	0	4,858	45,000	9.3
2058	94.83	250	4.3	0	4,640	45,000	9.7

North and Central (Estuarine) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	112.42	250	4.3	0	5,500	45,000	8.2
2018	111.67	250	4.3	0	5,464	45,000	8.2
2028	106.38	250	4.3	0	5,204	45,000	8.6
2038	101.36	250	4.3	0	4,959	45,000	9.1
2048	96.62	250	4.3	0	4,727	45,000	9.5
2058	92.16	250	4.3	0	4,509	45,000	10.0

North and Central (Riparian) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	112.33	250	4.3	0	5,496	45,000	8.2
2018	111.59	250	4.3	0	5,460	45,000	8.2
2028	106.30	250	4.3	0	5,201	45,000	8.7
2038	101.28	250	4.3	0	4,955	45,000	9.1
2048	96.54	250	4.3	0	4,723	45,000	9.5
2058	92.08	250	4.3	0	4,505	45,000	10.0

North and South (Seadrift) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	108.84	250	4.3	0	5,325	45,000	8.5
2018	111.99	250	4.3	0	5,479	45,000	8.2
2028	106.69	250	4.3	0	5,220	45,000	8.6
2038	101.67	250	4.3	0	4,974	45,000	9.0
2048	96.94	250	4.3	0	4,743	45,000	9.5
2058	92.48	250	4.3	0	4,524	45,000	9.9

North and South (No Seadrift) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	101.72	250	4.3	0	4,977	45,000	9.0
2018	102.08	250	4.3	0	4,994	45,000	9.0
2028	96.78	250	4.3	0	4,735	45,000	9.5
2038	91.77	250	4.3	0	4,490	45,000	10.0
2048	87.03	250	4.3	0	4,258	45,000	10.6
2058	82.57	250	4.3	0	4,040	45,000	11.1

Central (Estuarine) and South (Seadrift) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	109.60	250	4.3	0	5,362	45,000	8.4
2018	107.71	250	4.3	0	5,270	45,000	8.5
2028	102.42	250	4.3	0	5,011	45,000	9.0
2038	97.40	250	4.3	0	4,765	45,000	9.4
2048	92.66	250	4.3	0	4,533	45,000	9.9
2058	88.20	250	4.3	0	4,315	45,000	10.4

Central (Estuarine) and South (No Seadrift) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	102.48	250	4.3	0	5,014	45,000	9.0
2018	97.81	250	4.3	0	4,785	45,000	9.4
2028	92.51	250	4.3	0	4,526	45,000	9.9
2038	87.49	250	4.3	0	4,280	45,000	10.5
2048	82.75	250	4.3	0	4,049	45,000	11.1
2058	78.29	250	4.3	0	3,830	45,000	11.7

Central (Riparian) and South (Seadrift) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	109.51	250	4.3	0	5,358	45,000	8.4
2018	107.63	250	4.3	0	5,266	45,000	8.5
2028	102.34	250	4.3	0	5,007	45,000	9.0
2038	97.32	250	4.3	0	4,761	45,000	9.5
2048	92.58	250	4.3	0	4,529	45,000	9.9
2058	88.12	250	4.3	0	4,311	45,000	10.4

Central (Riparian) and South (No Seadrift) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	102.39	250	4.3	0	5,009	45,000	9.0
2018	97.73	250	4.3	0	4,781	45,000	9.4
2028	92.43	250	4.3	0	4,522	45,000	10.0
2038	87.41	250	4.3	0	4,277	45,000	10.5
2048	82.67	250	4.3	0	4,045	45,000	11.1
2058	78.21	250	4.3	0	3,826	45,000	11.8

North Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	99.94	250	4.3	0	4,890	45,000	9.2
2018	99.33	250	4.3	0	4,860	45,000	9.3
2028	94.03	250	4.3	0	4,601	45,000	9.8
2038	89.02	250	4.3	0	4,355	45,000	10.3
2048	84.28	250	4.3	0	4,123	45,000	10.9
2058.00	80	250	4.3	0	3,905	45,000	11.5

Central (Estuarine) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	100.70	250	4.3	0	4,927	45,000	9.1
2018	95.05	250	4.3	0	4,651	45,000	9.7
2028	89.76	250	4.3	0	4,391	45,000	10.2
2038	84.74	250	4.3	0	4,146	45,000	10.9
2048	80.00	250	4.3	0	3,914	45,000	11.5
2058	75.54	250	4.3	0	3,696	45,000	12.2

Central (Riparian) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	100.61	250	4.3	0	4,922	45,000	9.1
2018	94.98	250	4.3	0	4,647	45,000	9.7
2028	89.68	250	4.3	0	4,387	45,000	10.3
2038	84.66	250	4.3	0	4,142	45,000	10.9
2048	79.92	250	4.3	0	3,910	45,000	11.5
2058	75.46	250	4.3	0	3,692	45,000	12.2

South (Seadrift) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	96.78	250	4.3	0	4,735	45,000	9.5
2018	95.03	250	4.3	0	4,649	45,000	9.7
2028	89.74	250	4.3	0	4,390	45,000	10.2
2038	84.72	250	4.3	0	4,145	45,000	10.9
2048	79.98	250	4.3	0	3,913	45,000	11.5
2058	75.52	250	4.3	0	3,695	45,000	12.2

South (No Seadrift) Alternative

Year	Tidal Prism million ft ³	Inlet Width feet	Tide Range feet	Fresh Water ft ³ /sec	Tidal Power ft-lbs/sec	Wave Power ft-lbs/sec	Closure Index
1968	118.84	250	4.3	0	5,814	45,000	7.7
1978	101.09	250	4.3	0	4,946	45,000	9.1
1988	92.16	250	4.3	0	4,509	45,000	10.0
1998	87.87	250	4.3	0	4,299	45,000	10.5
2008	89.65	250	4.3	0	4,386	45,000	10.3
2018	85.13	250	4.3	0	4,165	45,000	10.8
2028	79.83	250	4.3	0	3,906	45,000	11.5
2038	74.81	250	4.3	0	3,660	45,000	12.3
2048	70.07	250	4.3	0	3,428	45,000	13.1
2058	65.61	250	4.3	0	3,210	45,000	14.0

APPENDIX 22
HYDRAULIC NUMERICAL MODELING
SOURCE: KAMMAN HYDROLOGY
AND ENGINEERING, INC.

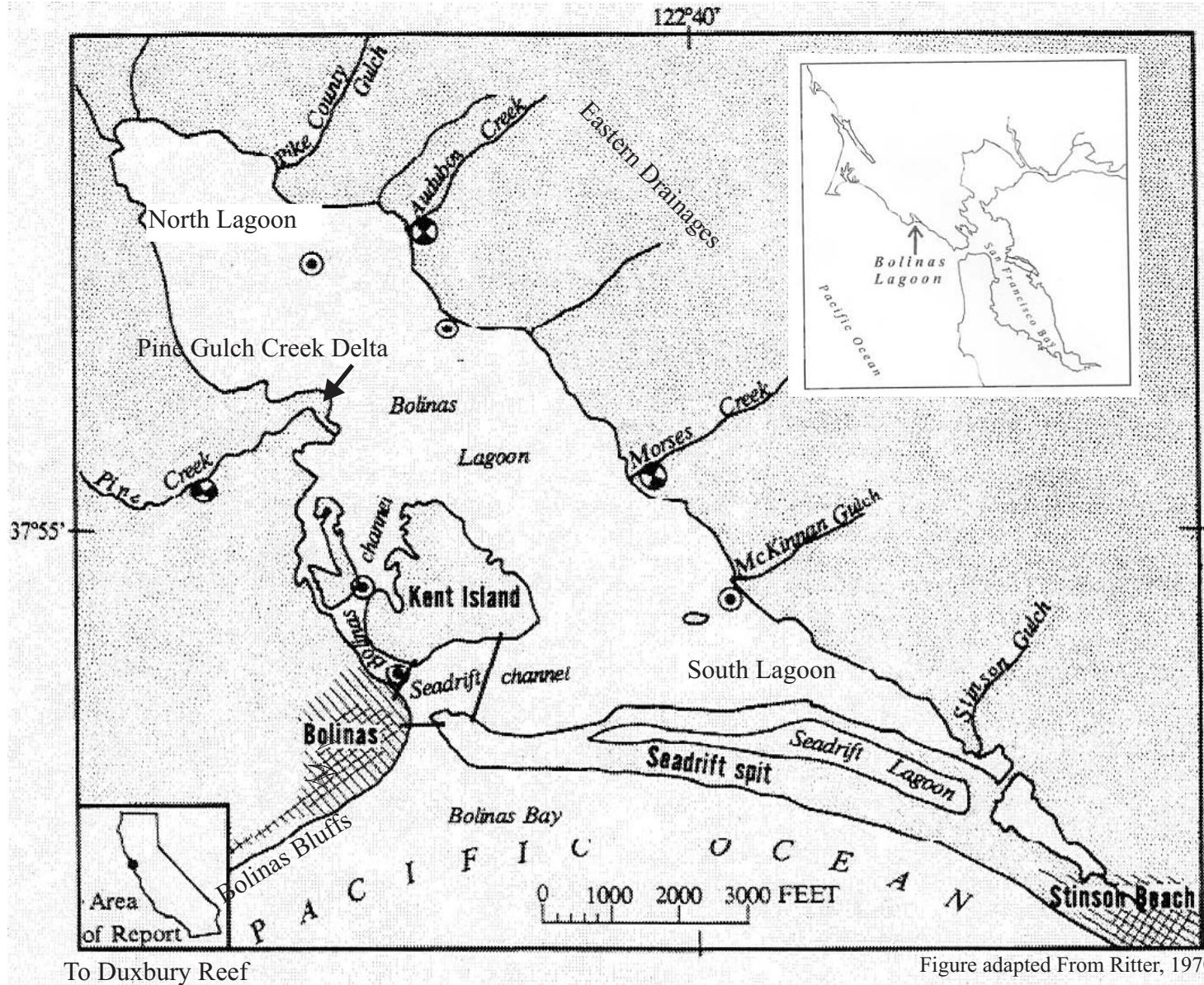
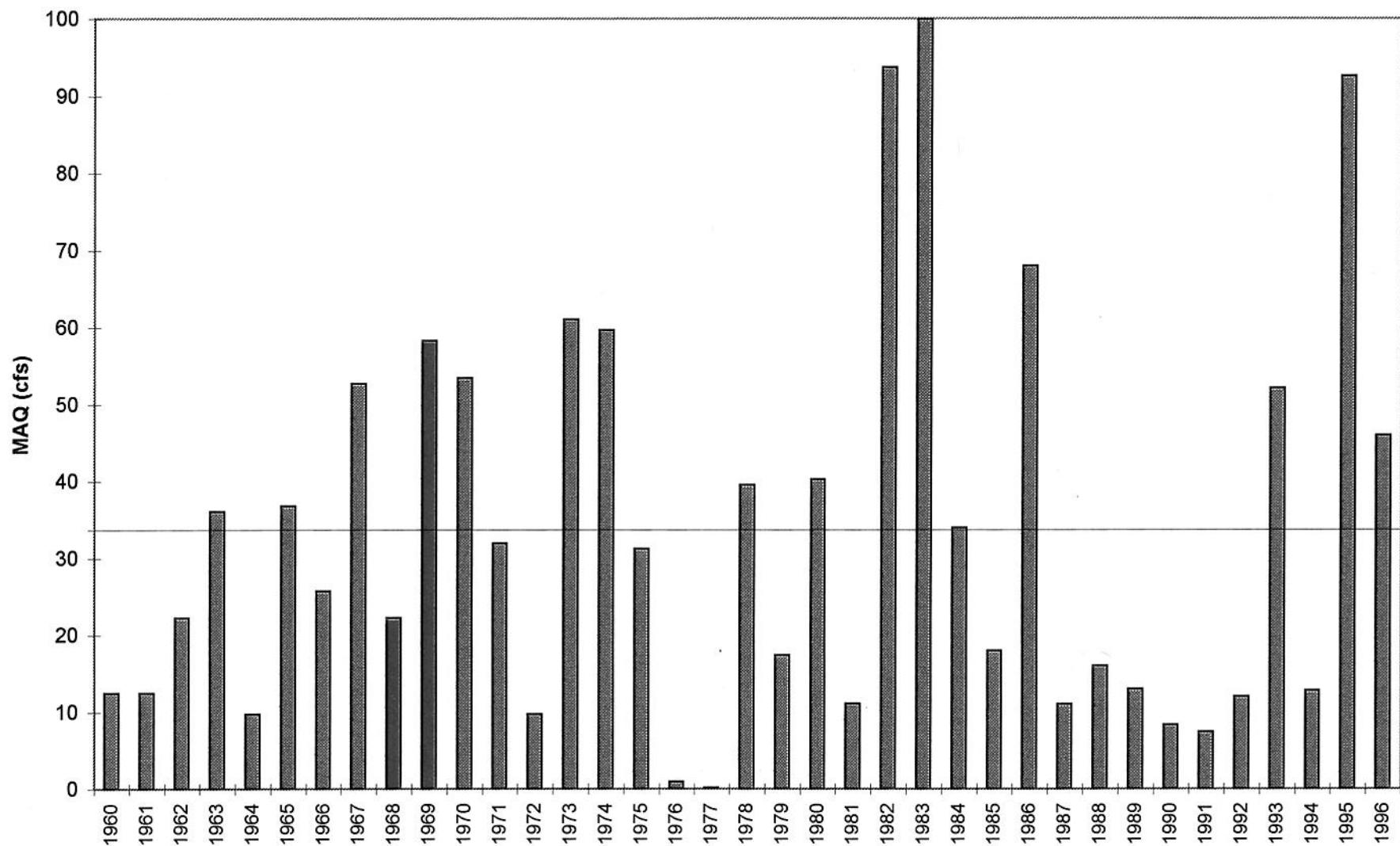


Figure 2.1: Bolinas Lagoon Location and Site Map

(Lagoon configuration circa 1970)

Figure 2.2: Mean Annual Flow (MAQ): Walker Cr. near Marshal



**Figure 2.3: Storm Discharges for Bolinas Lagoon Drainages:
Morses and Pine Gulch Creeks (Water Year 1968-1969)**

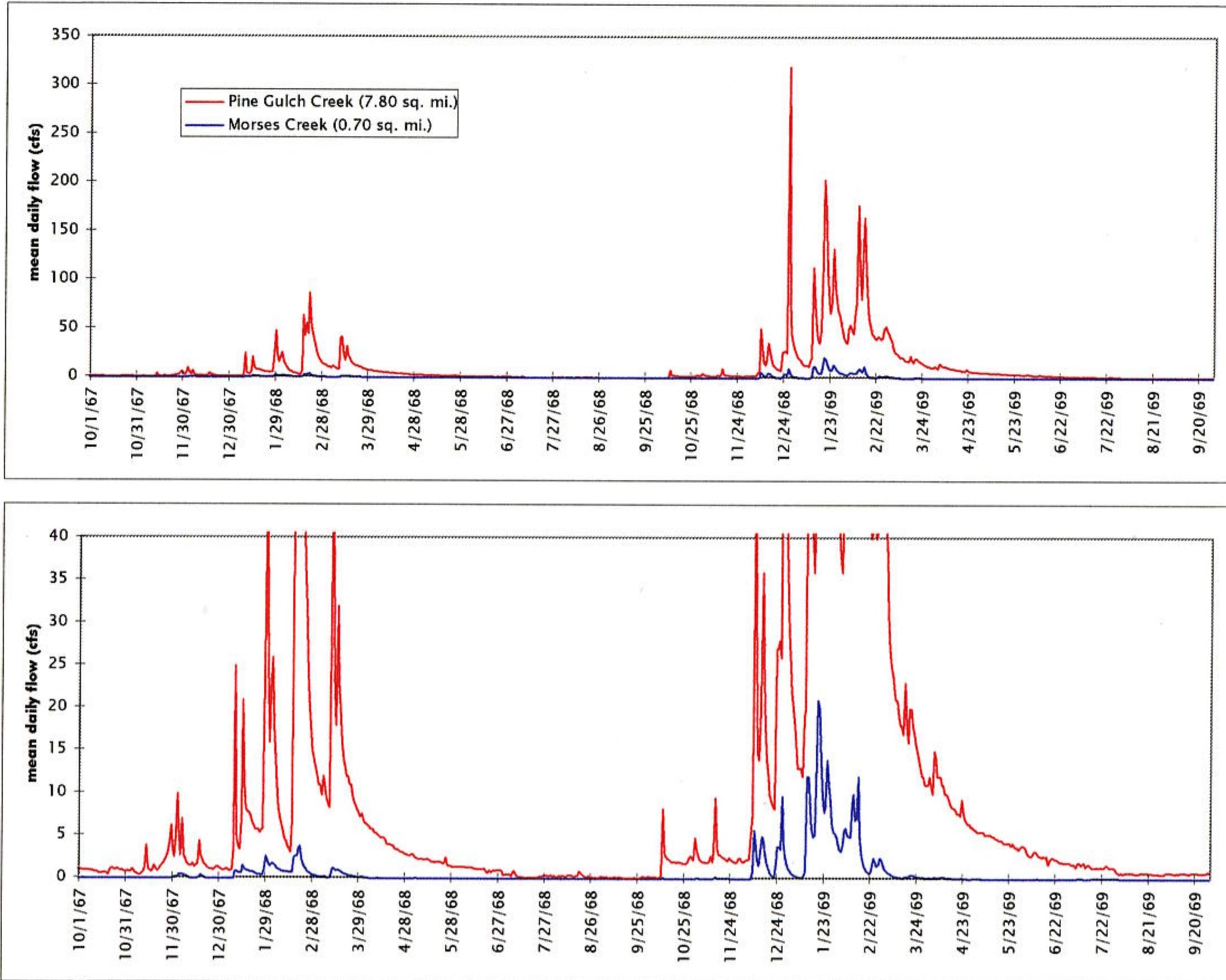
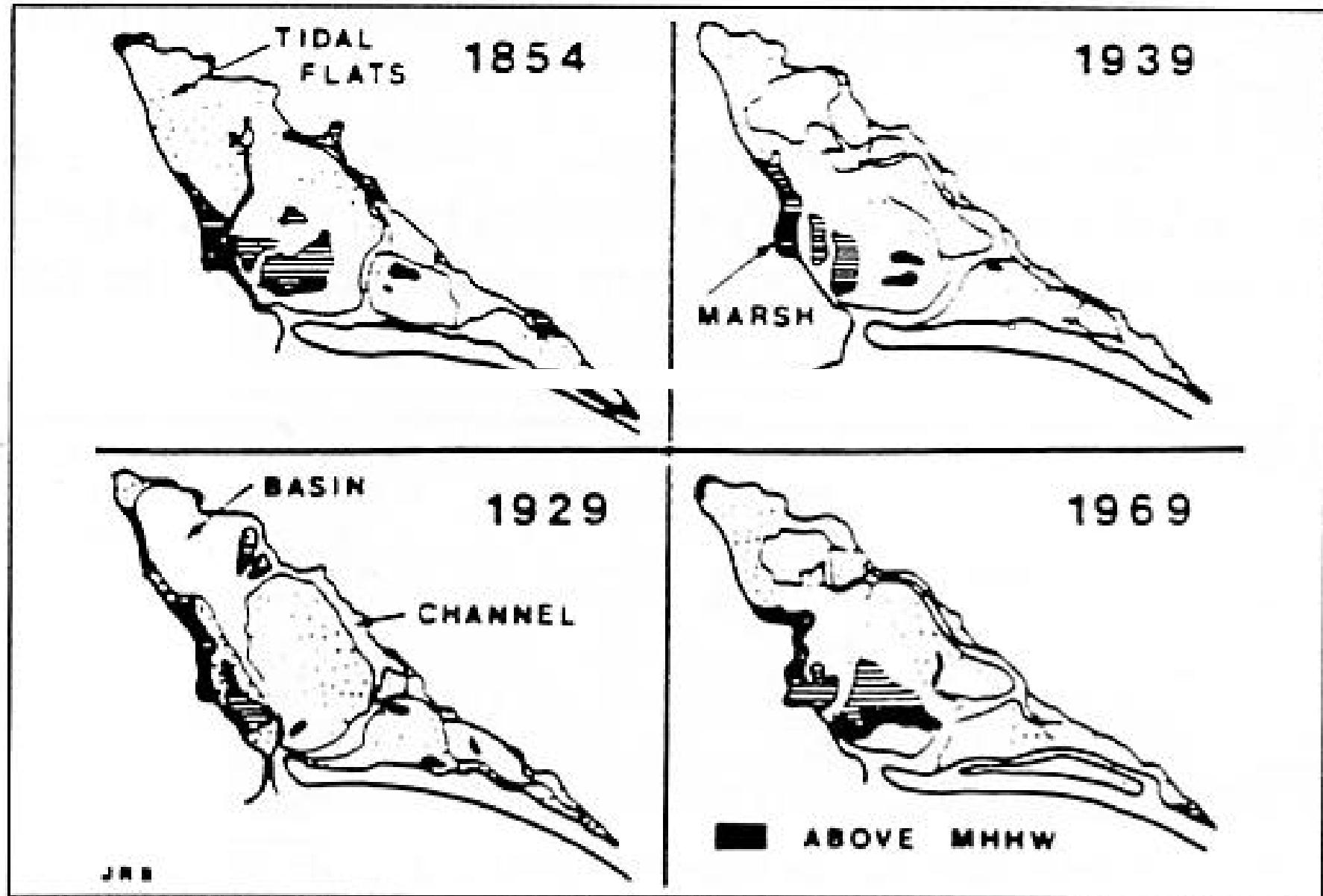


Figure 2.4: Sedimentation Patterns in Bolinas Lagoon (1858 to 1950)



Source: Ritter, 1970

Figure 2.5: Observed Water Levels: Bolinas Bay, Drakes Bay & San Francisco (Presidio)

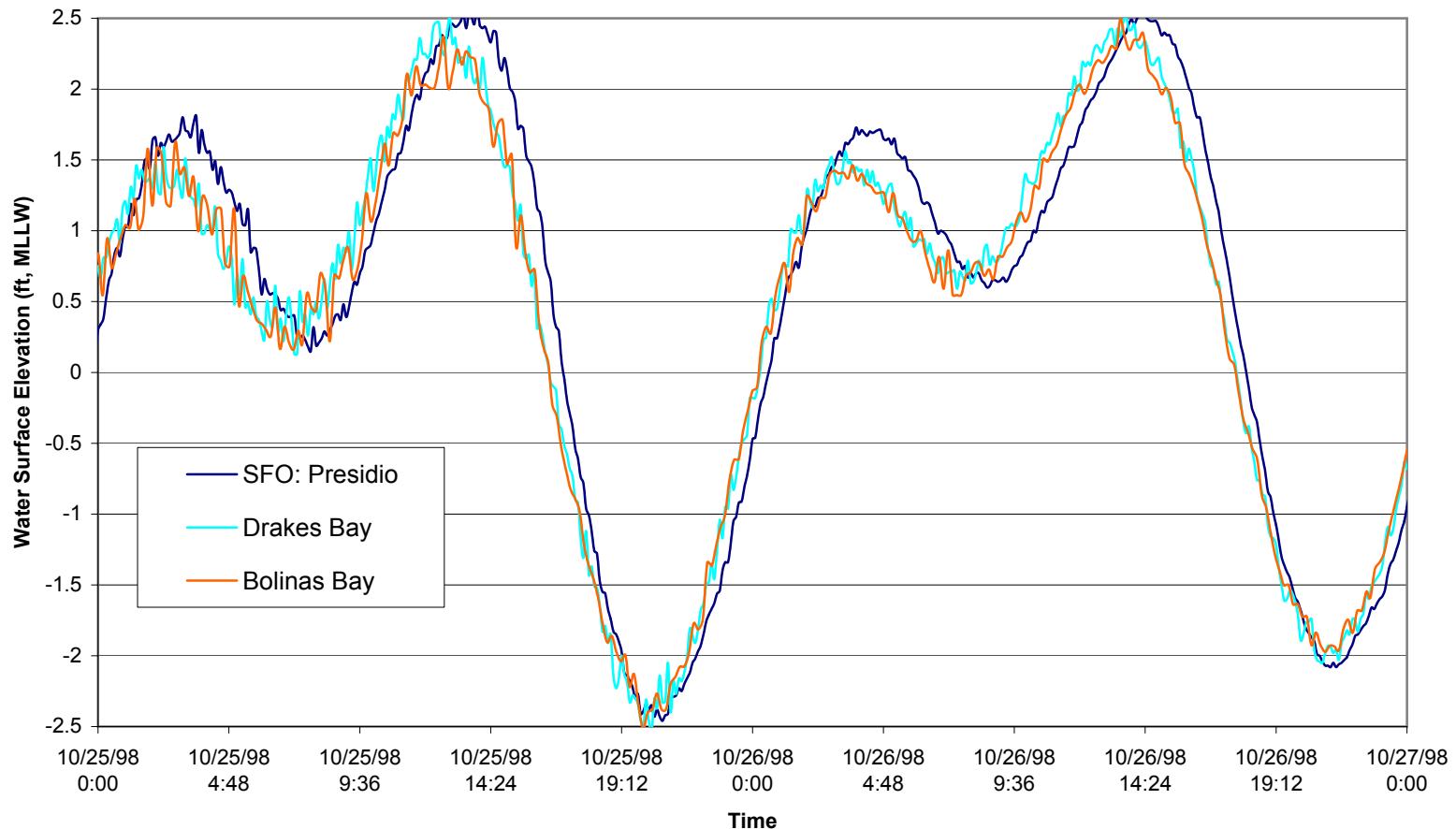


Figure 3.1: Bolinas Lagoon 1997



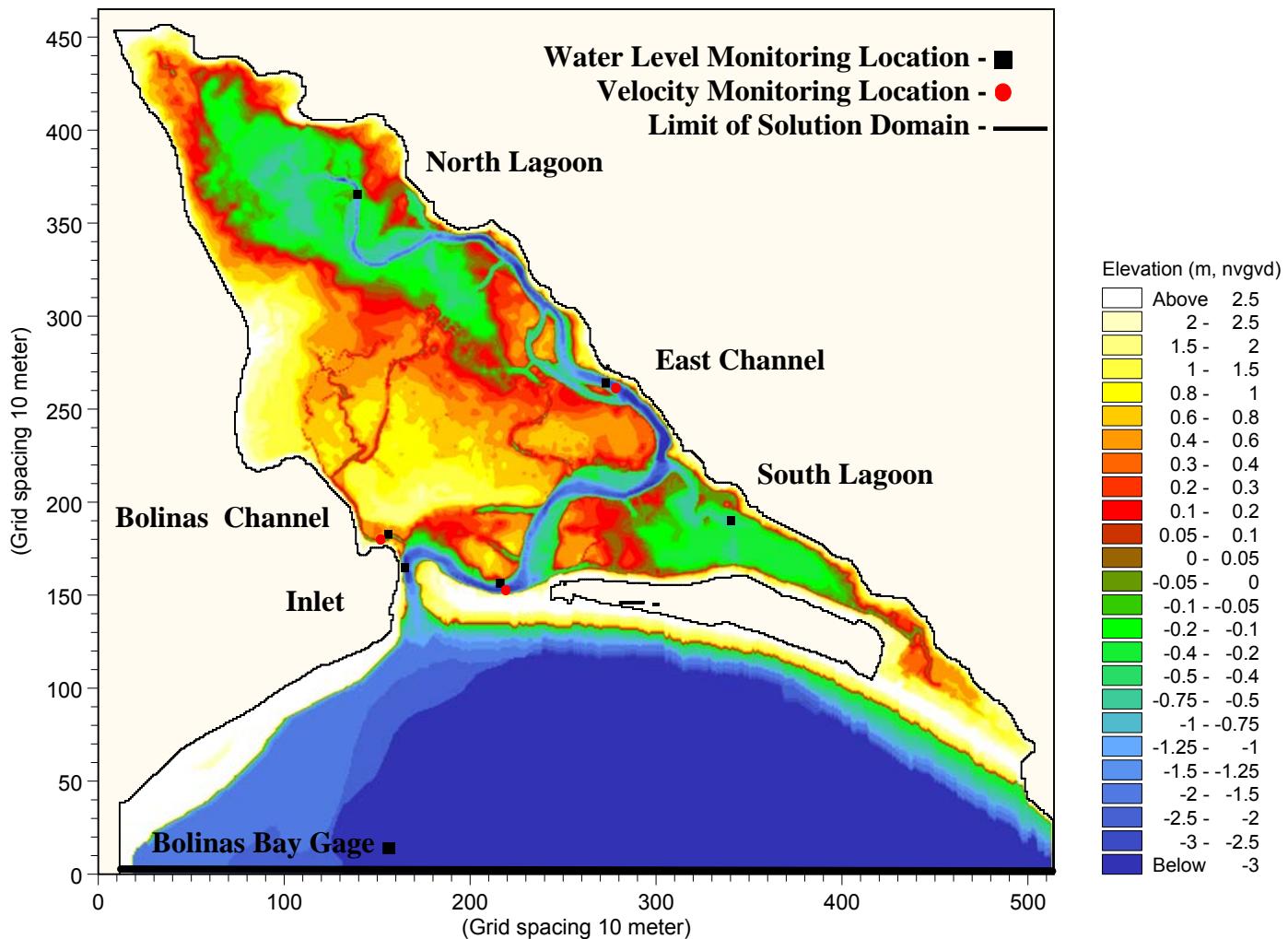


Figure 3.2: Bolinas Lagoon Existing Conditions (1998) Model Bathymetry

Figure 3.3: Bolinas Lagoon 1968

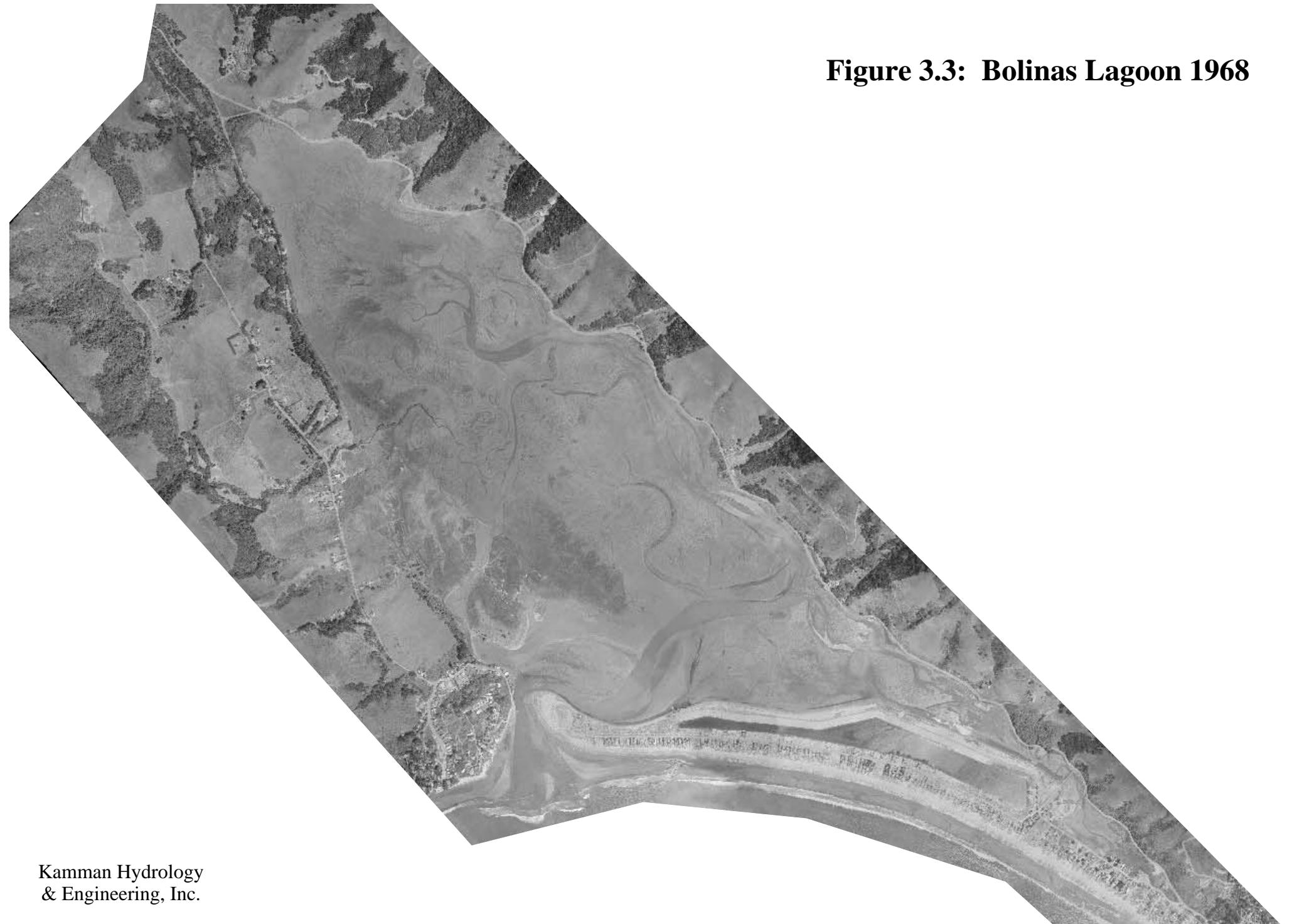


Figure 3.4: Fall 1998 Water Level Observations in Bolinas Bay

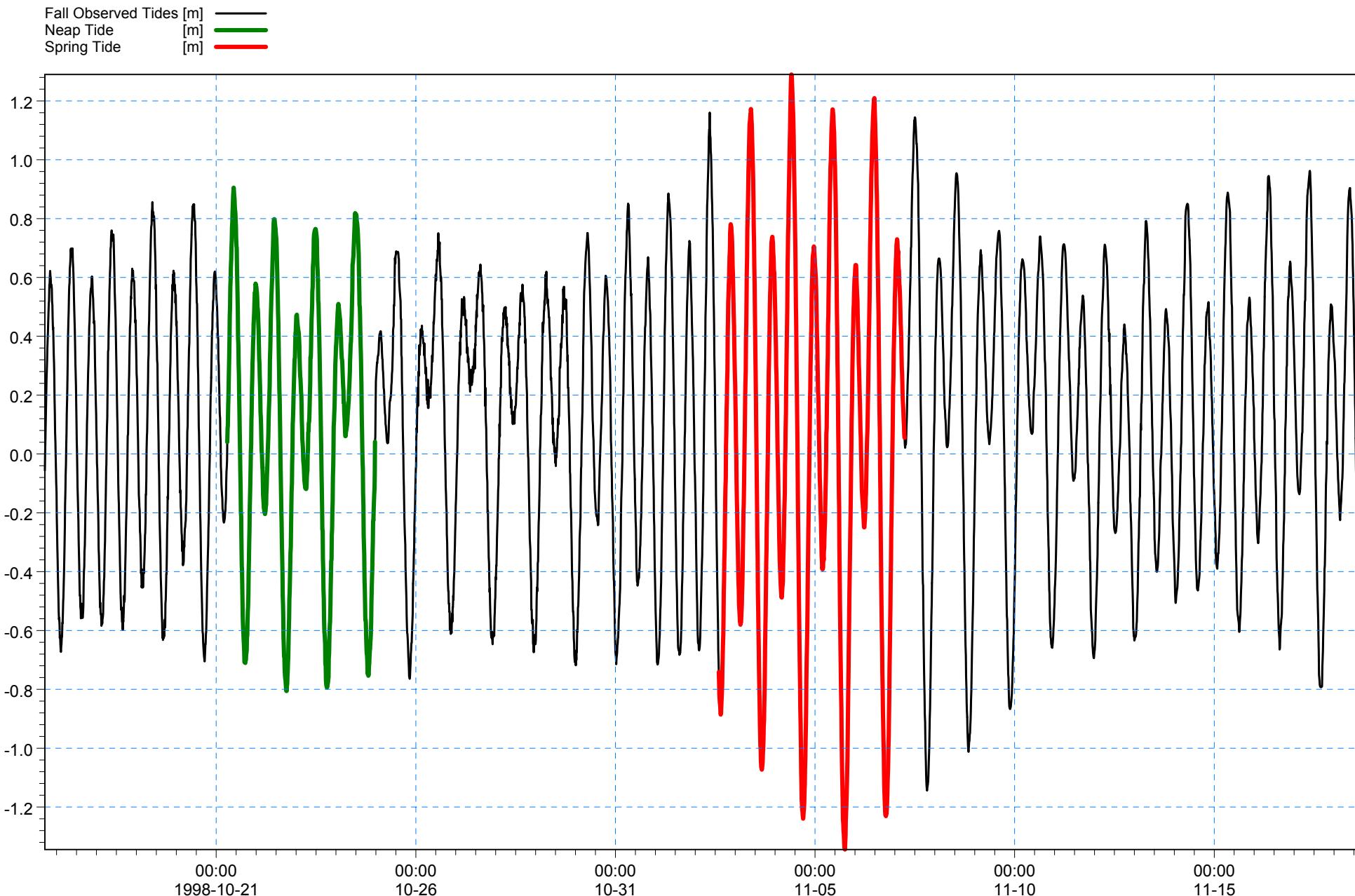


Figure 3.5a: Predicted and Observed Water Levels in Bolinas Bay (Fall 1998)

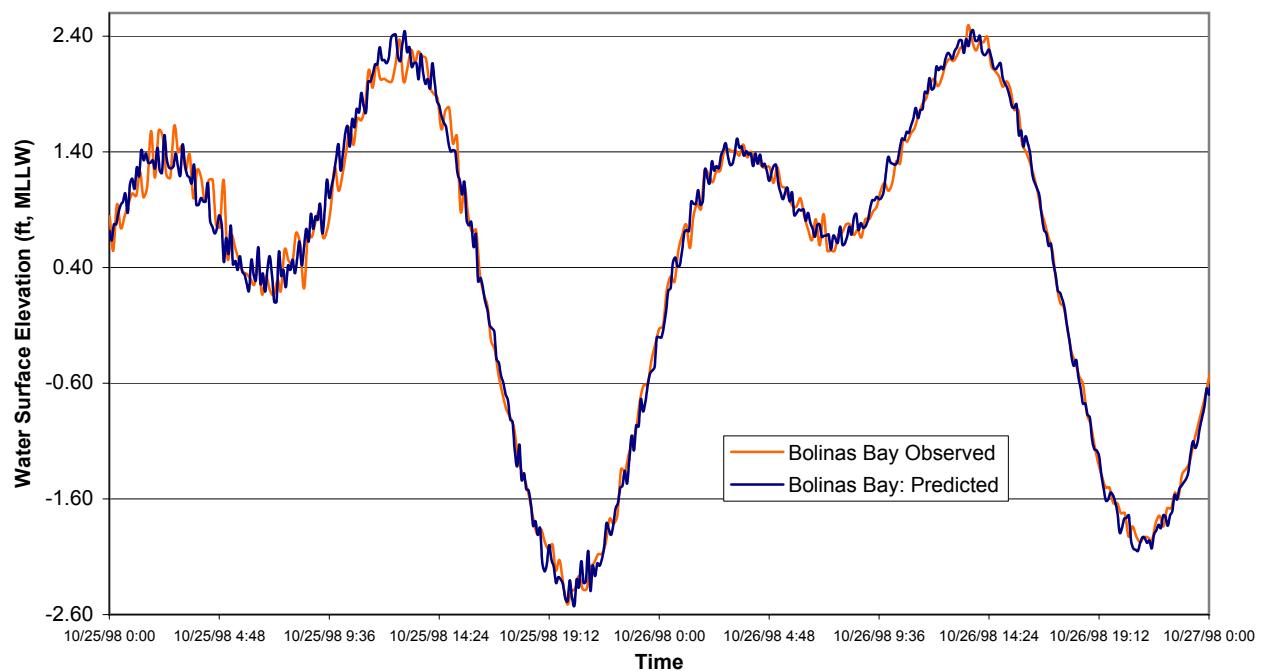


Figure 3.5b: Predicted Water Levels in Bolinas Bay (Spring 1998)

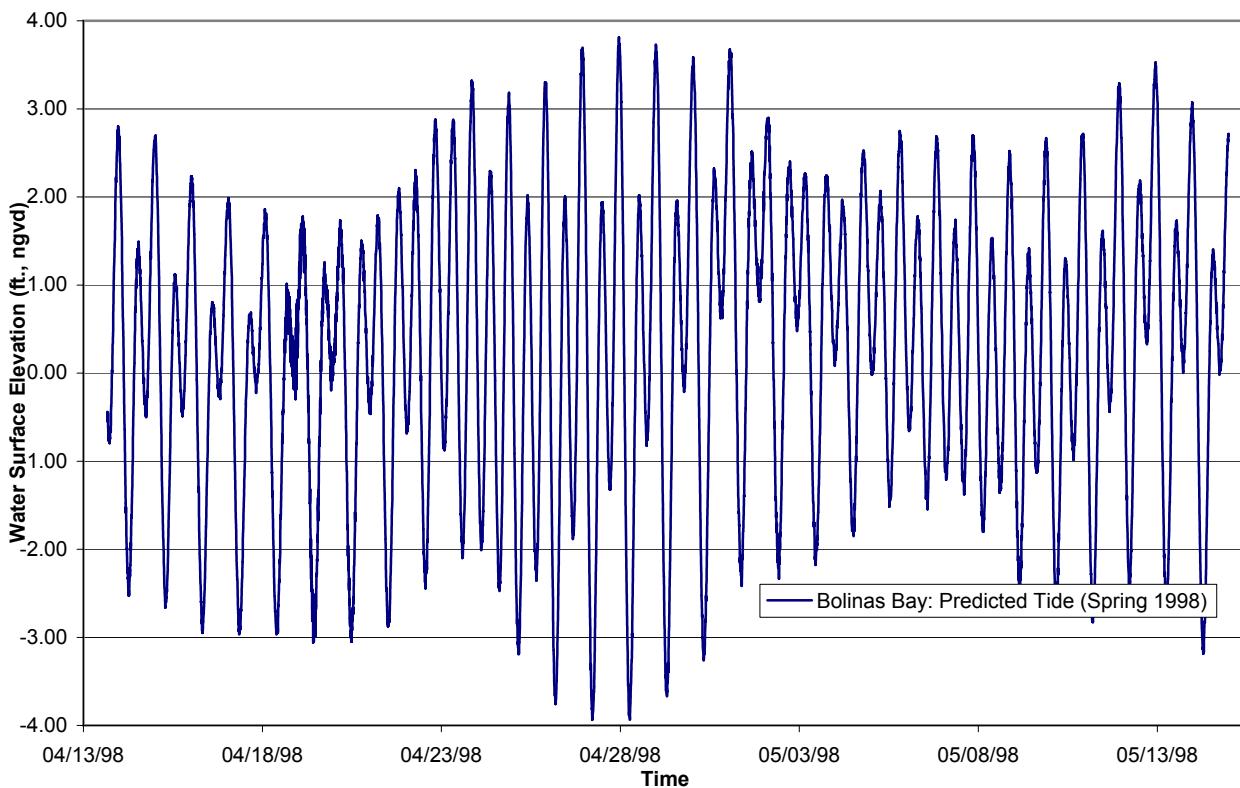


Figure 3.6: Bolinas Bay Mean Tidal Month

"Bolinas Bay Mean Tidal Month (ngvd) [m] —

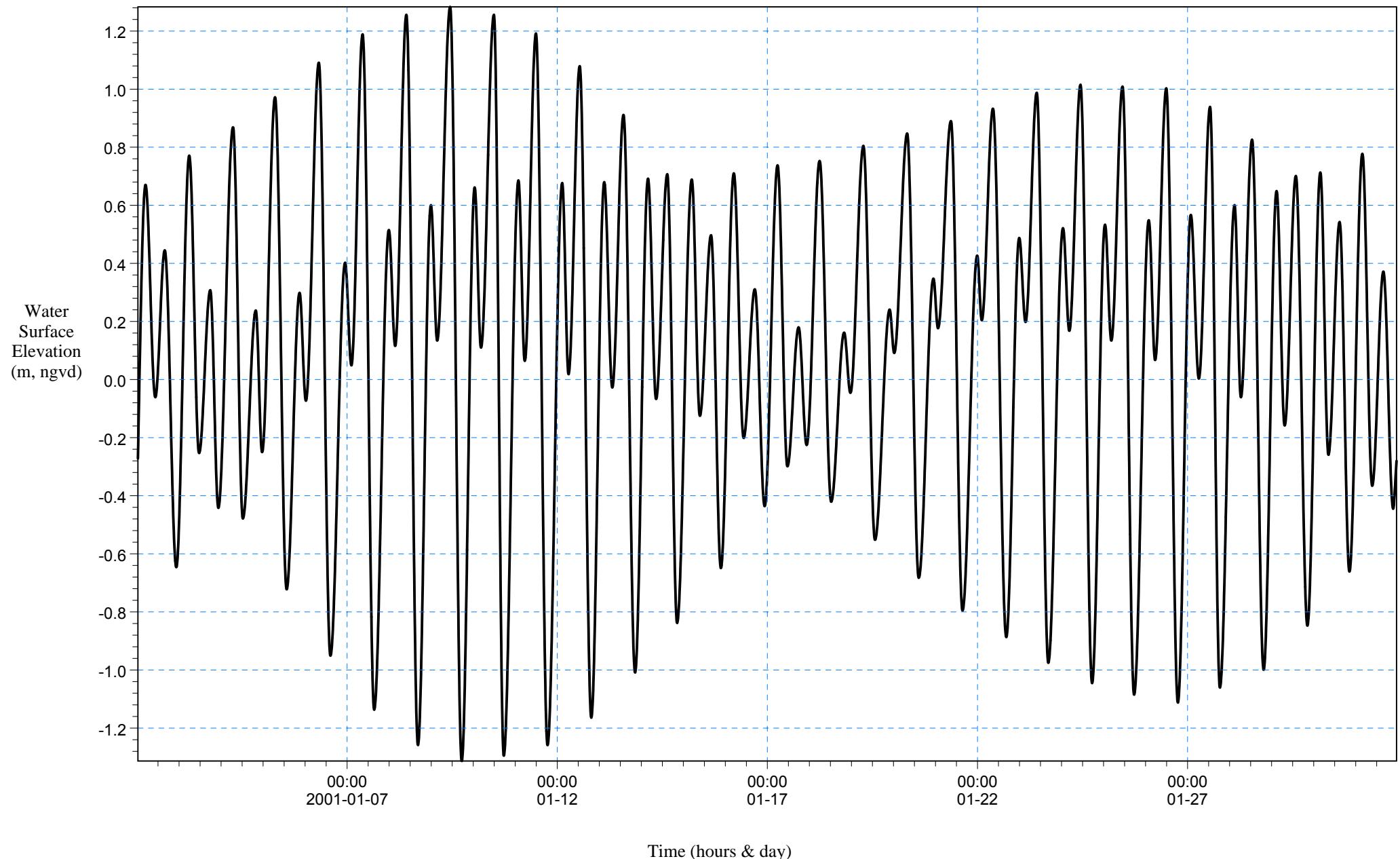


Figure 4.1:Resistance Elements (Current Conditions)

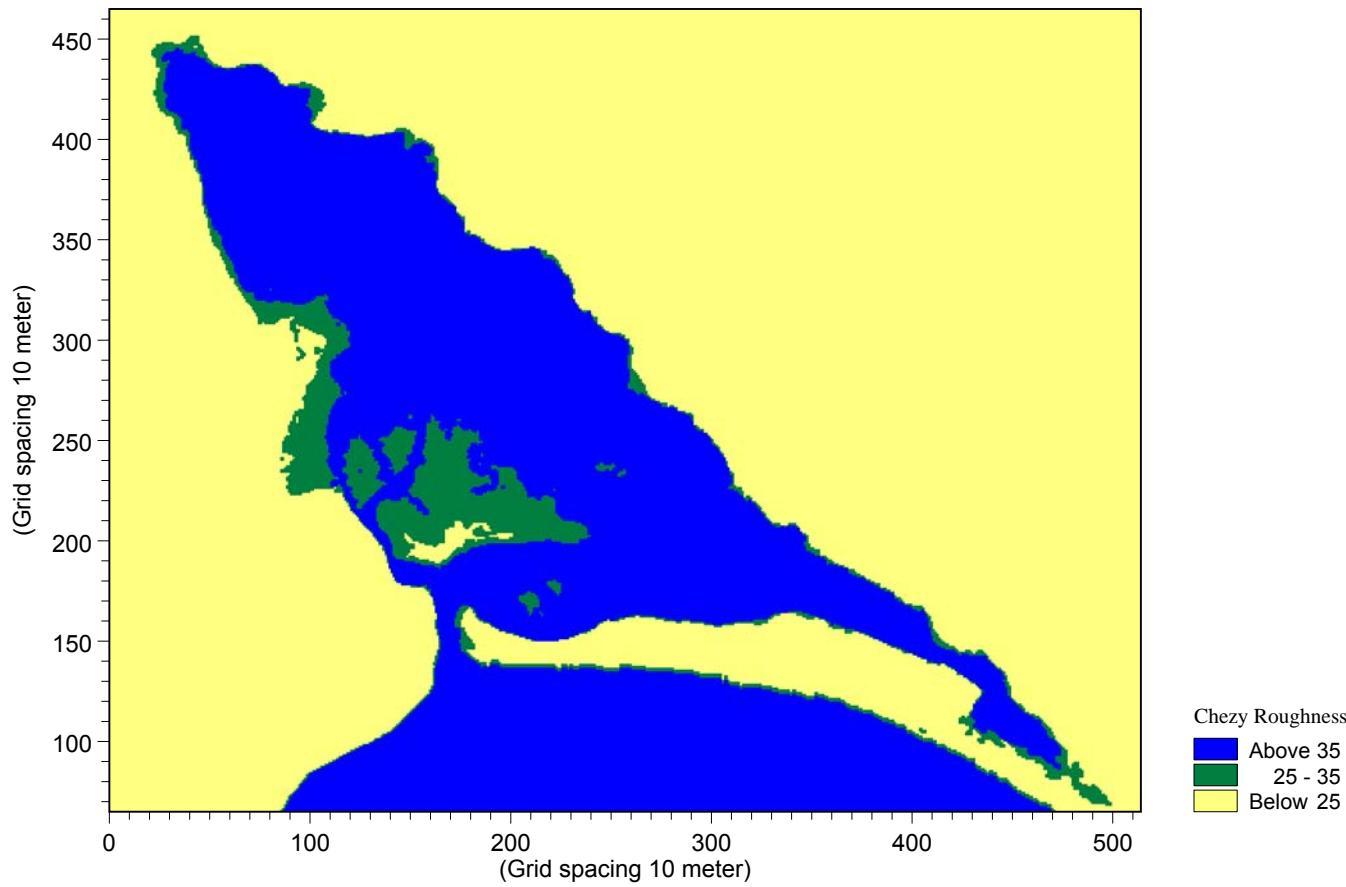
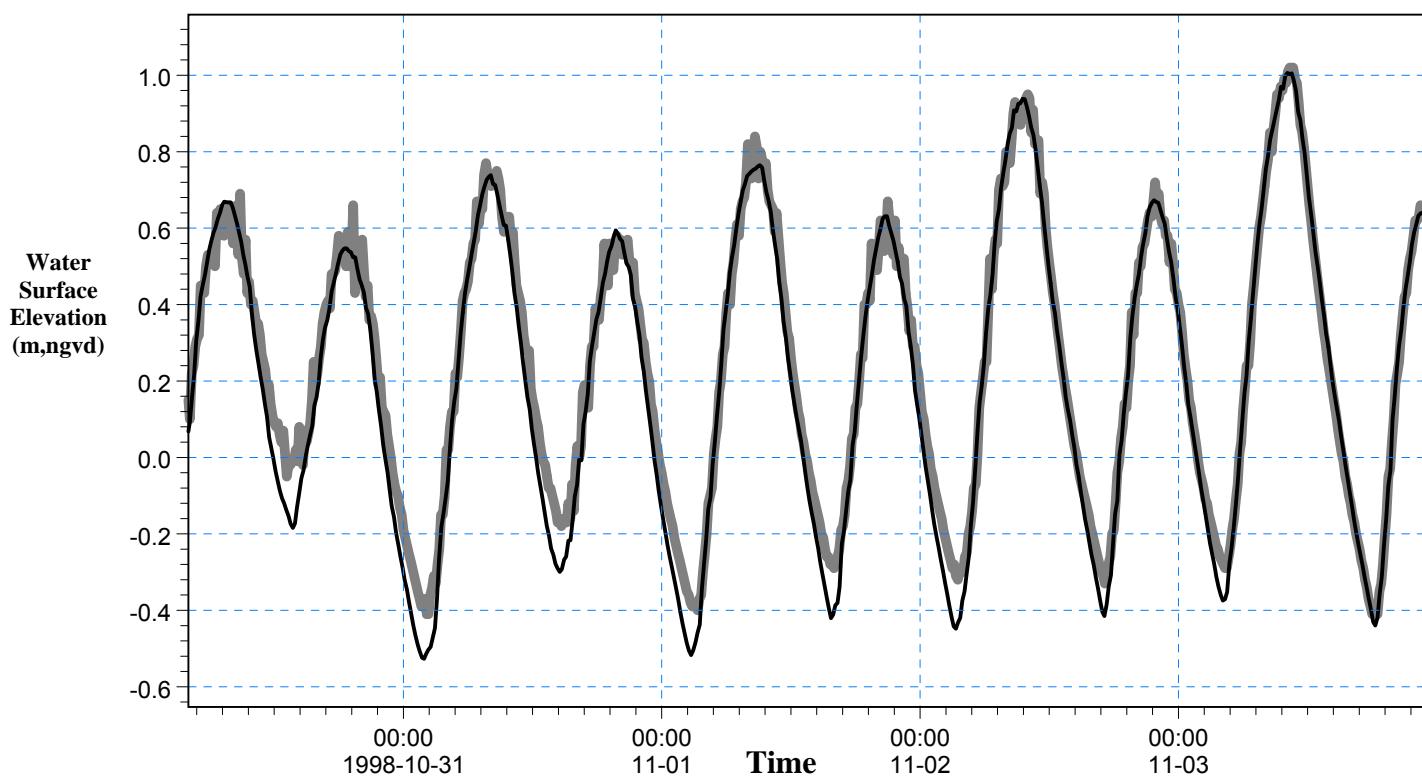


Figure 4.2: Calibrated and Observed Water Levels: West Lagoon

QCed Fall INLET [m] — QCed Fall INLET Calibration WSE [m] —

Figure 4.2a: Predicted And Observed (Fall 1998) Water Levels: Inlet Channel



QCed South Arm Observ. (Fall) [m] — QCed South Arm Observ. (Fall) Calibration WSE [m] —

Figure 4.2b: Predicted And Observed (Fall 1998) Water Levels: South Arm Channel

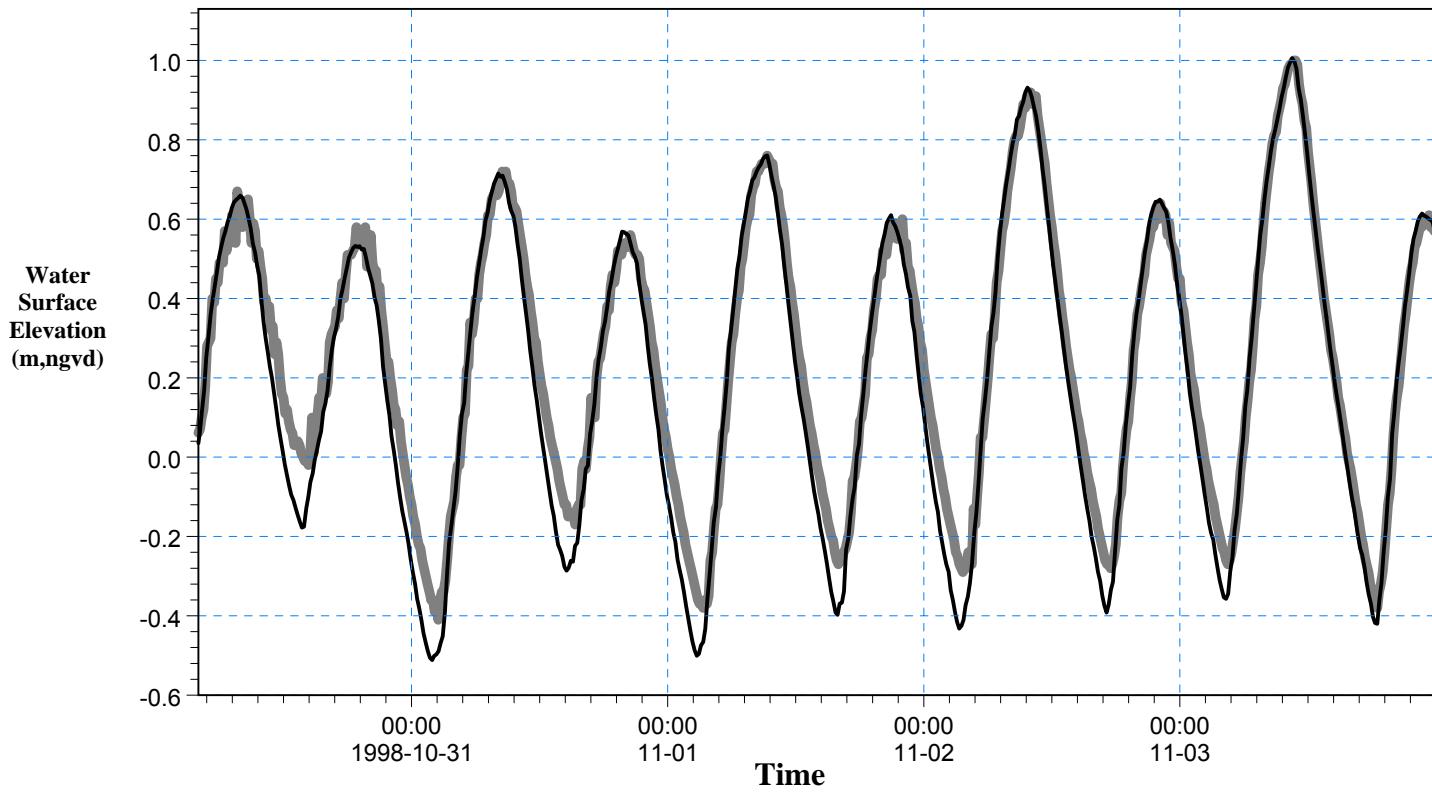
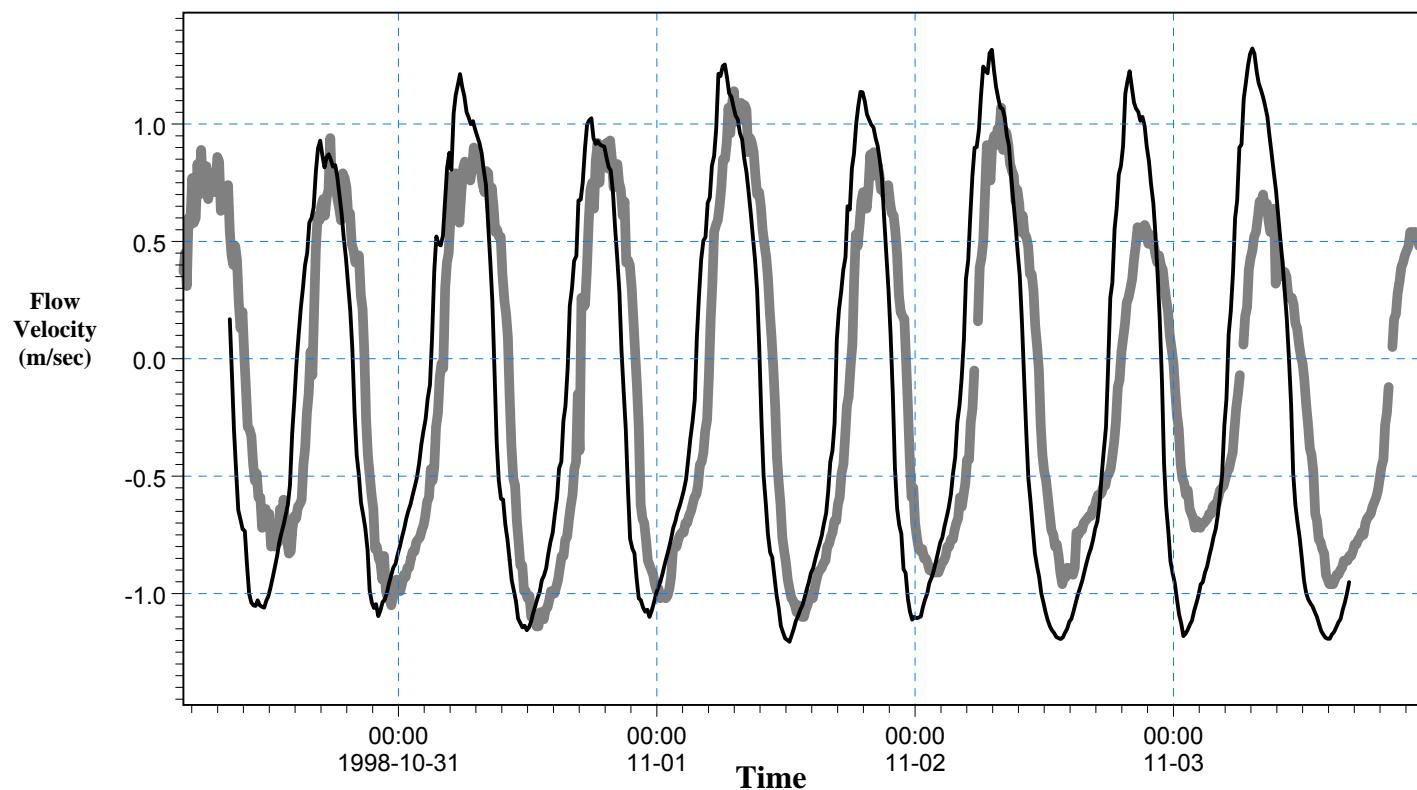


Figure 4.3: Calibrated and Observed Flow Velocities: South Arm Channel

South Arm Channel X- Velocity (Fall 1998) [m/s] —————
 South Arm: Calibration: Vel. X dir. [m/s] —————

Figure 4.3a: Velocities in X-Direction



South Arm Channel Y-Velocity (Fall 1998) [m/s] —————
 South Arm: Calibration: Vel. Y dir. [m/s] —————

Figure 4.3b: Velocities in Y-Direction

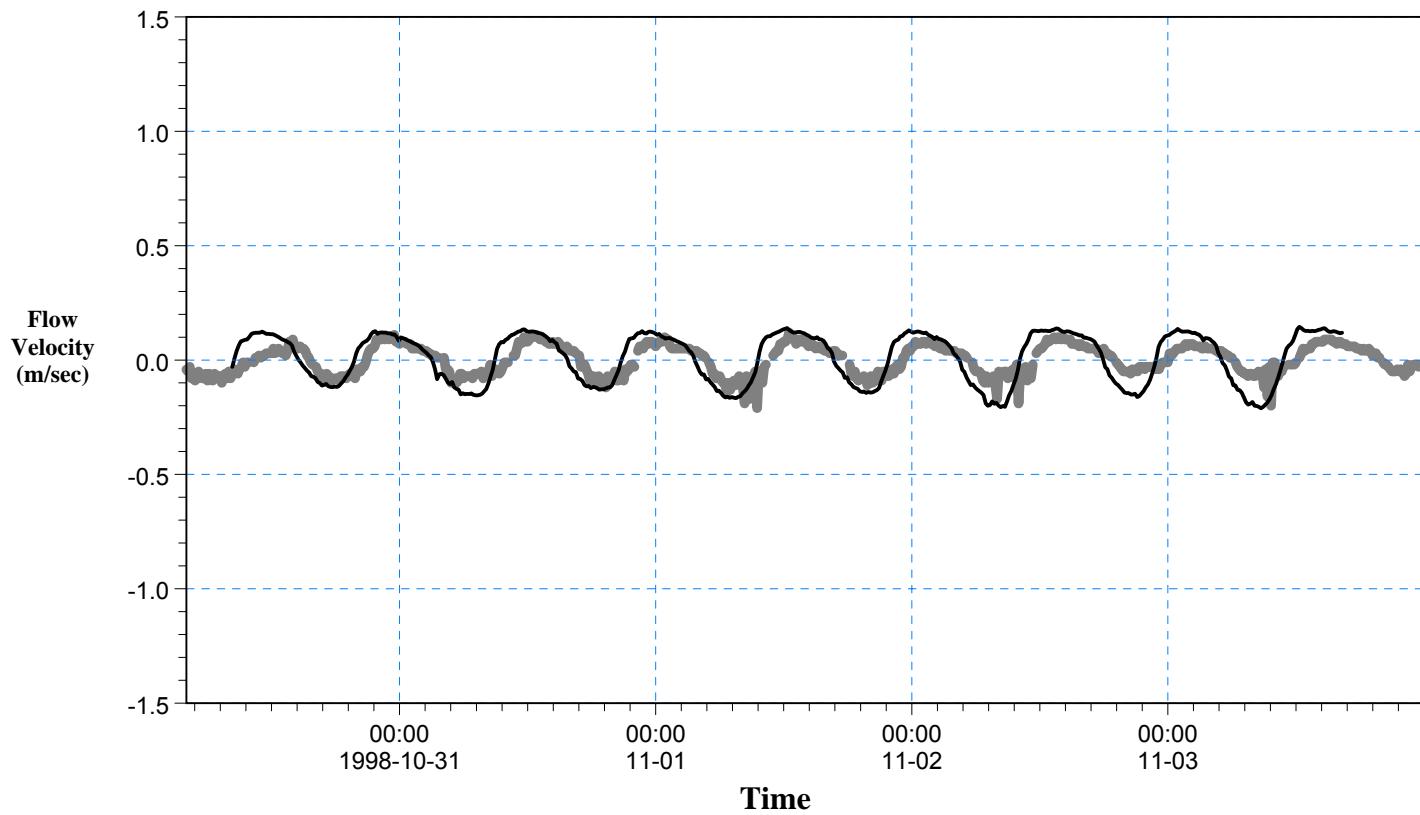


Figure 4.4: Calibrated and Observed Water Levels and Flow Velocities: Bolinas Channel

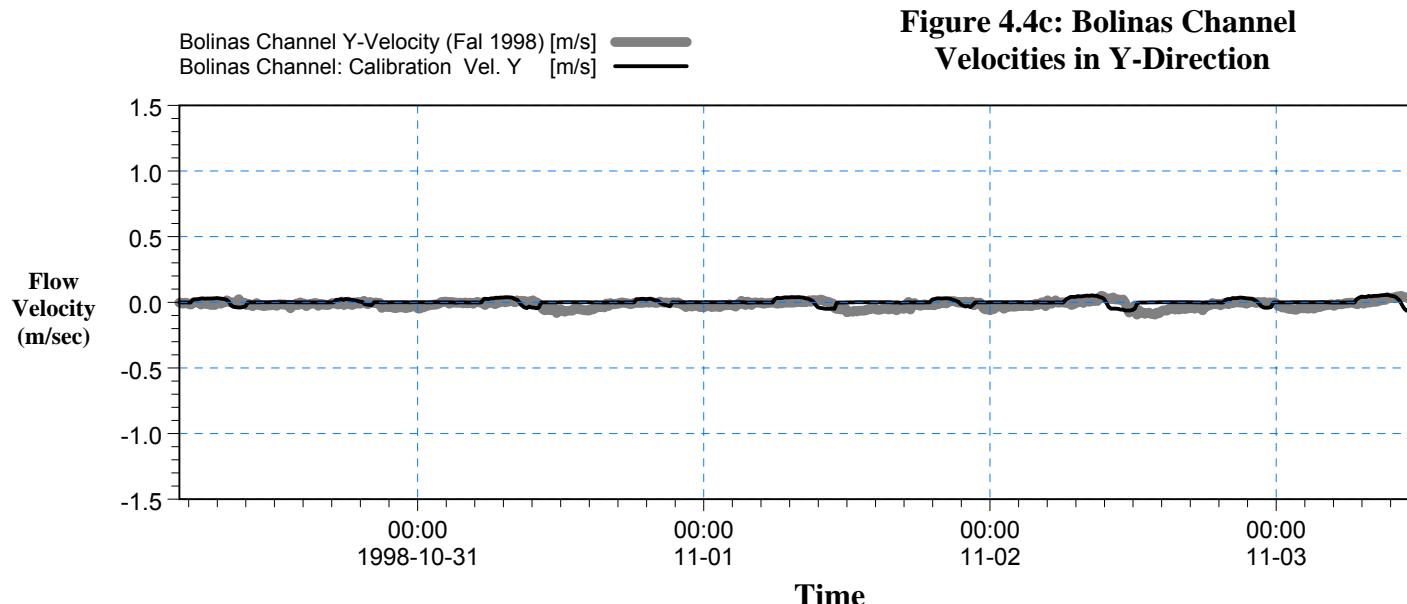
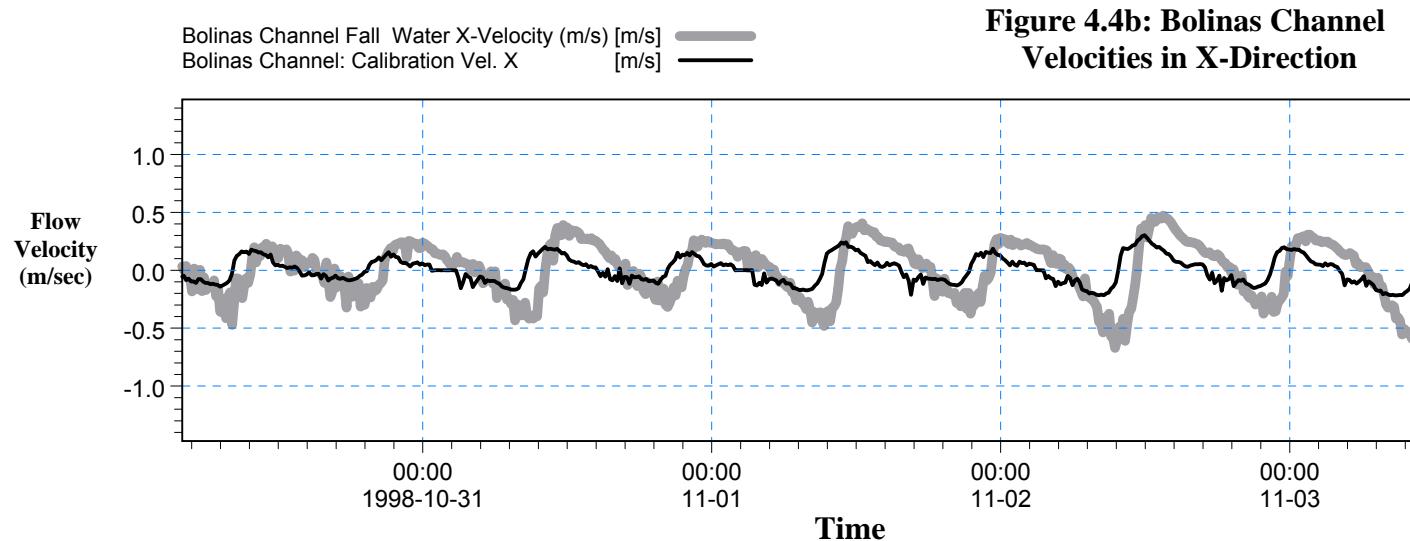
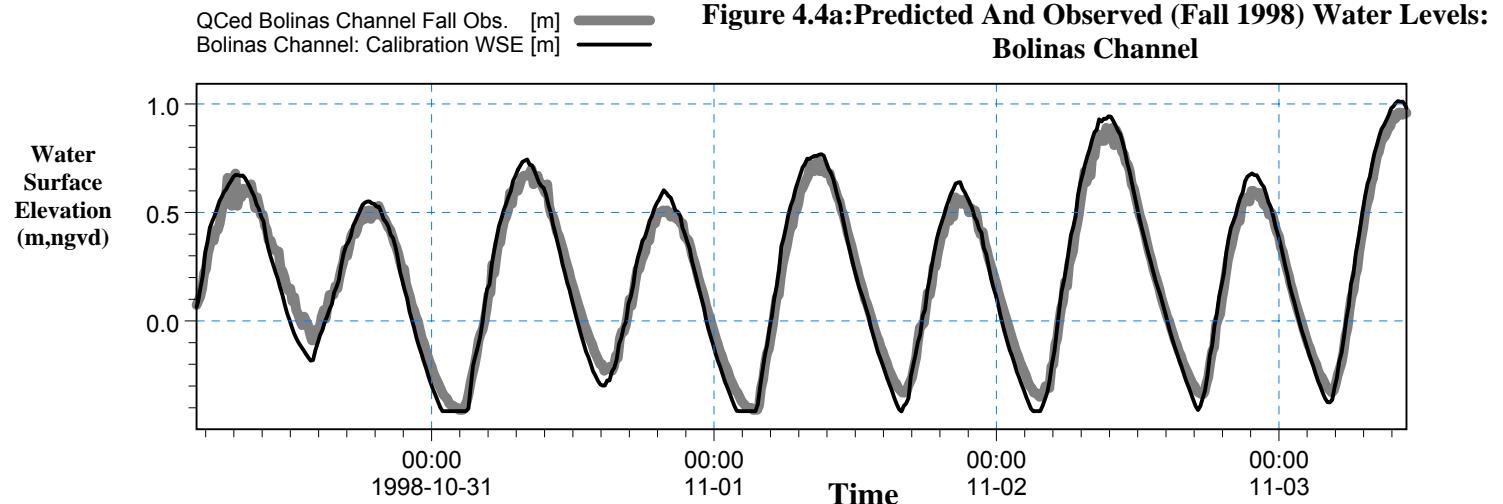


Figure 4.4b: Bolinas Channel Velocities in X-Direction

Figure 4.5: Calibrated and Observed Water Levels and Flow Velocities: East Channel

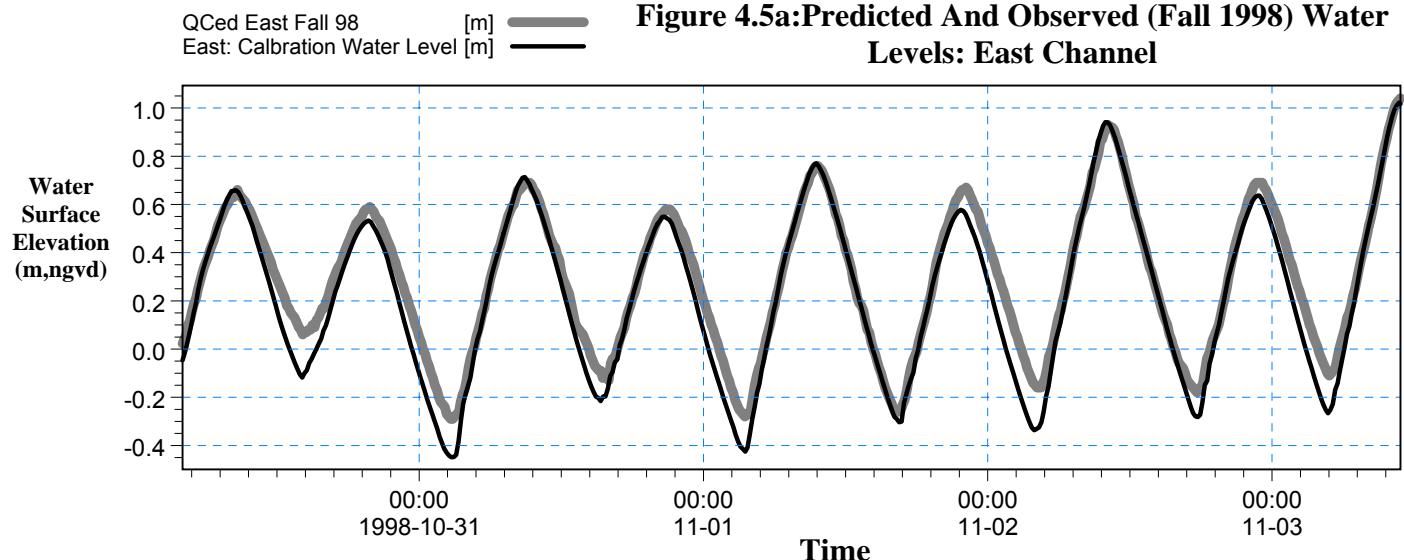


Figure 4.5a: Predicted And Observed (Fall 1998) Water Levels: East Channel

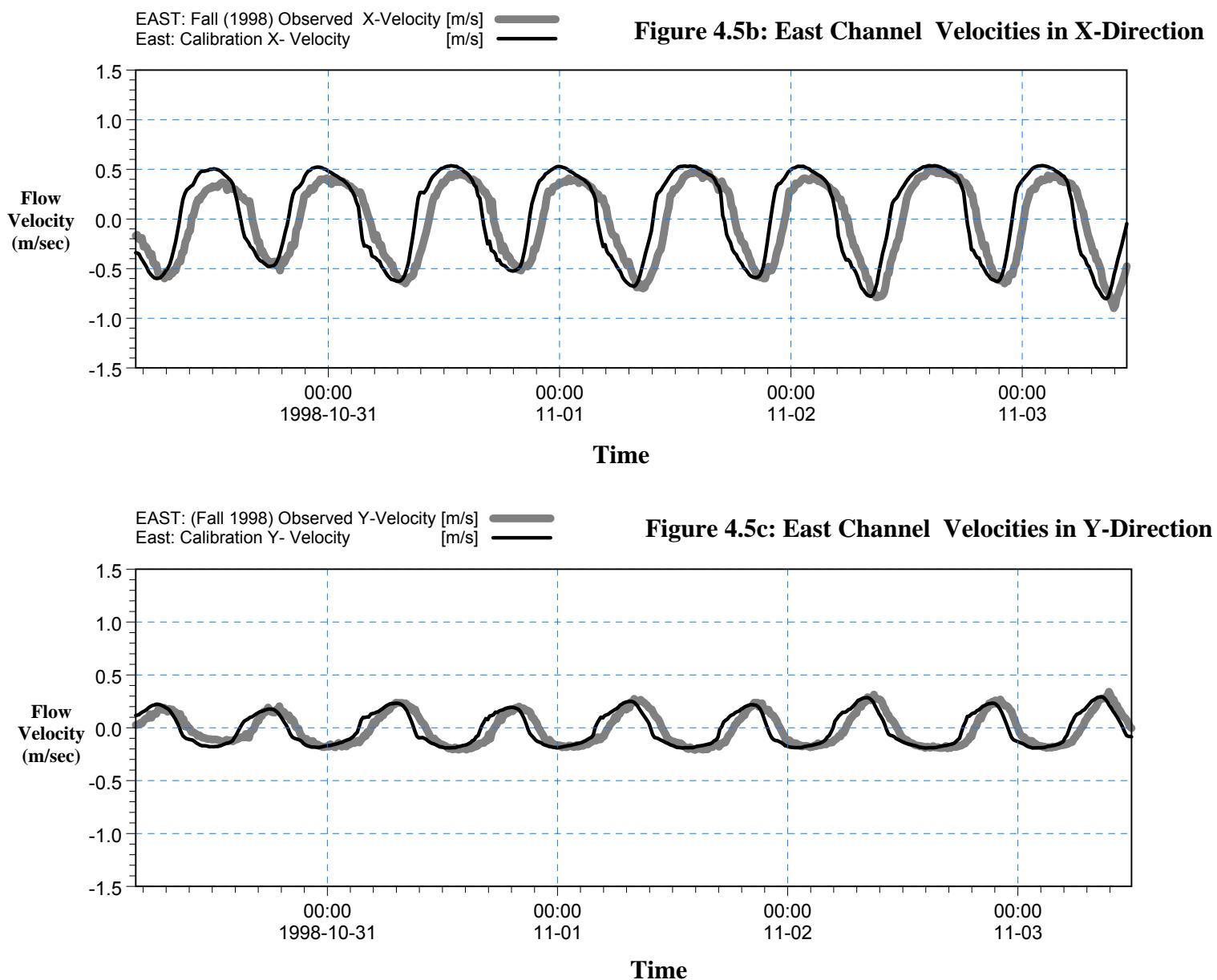


Figure 4.5c: East Channel Velocities in Y-Direction

Figure 4.6a: Calibrated and Observed Water Levels: North Lagoon

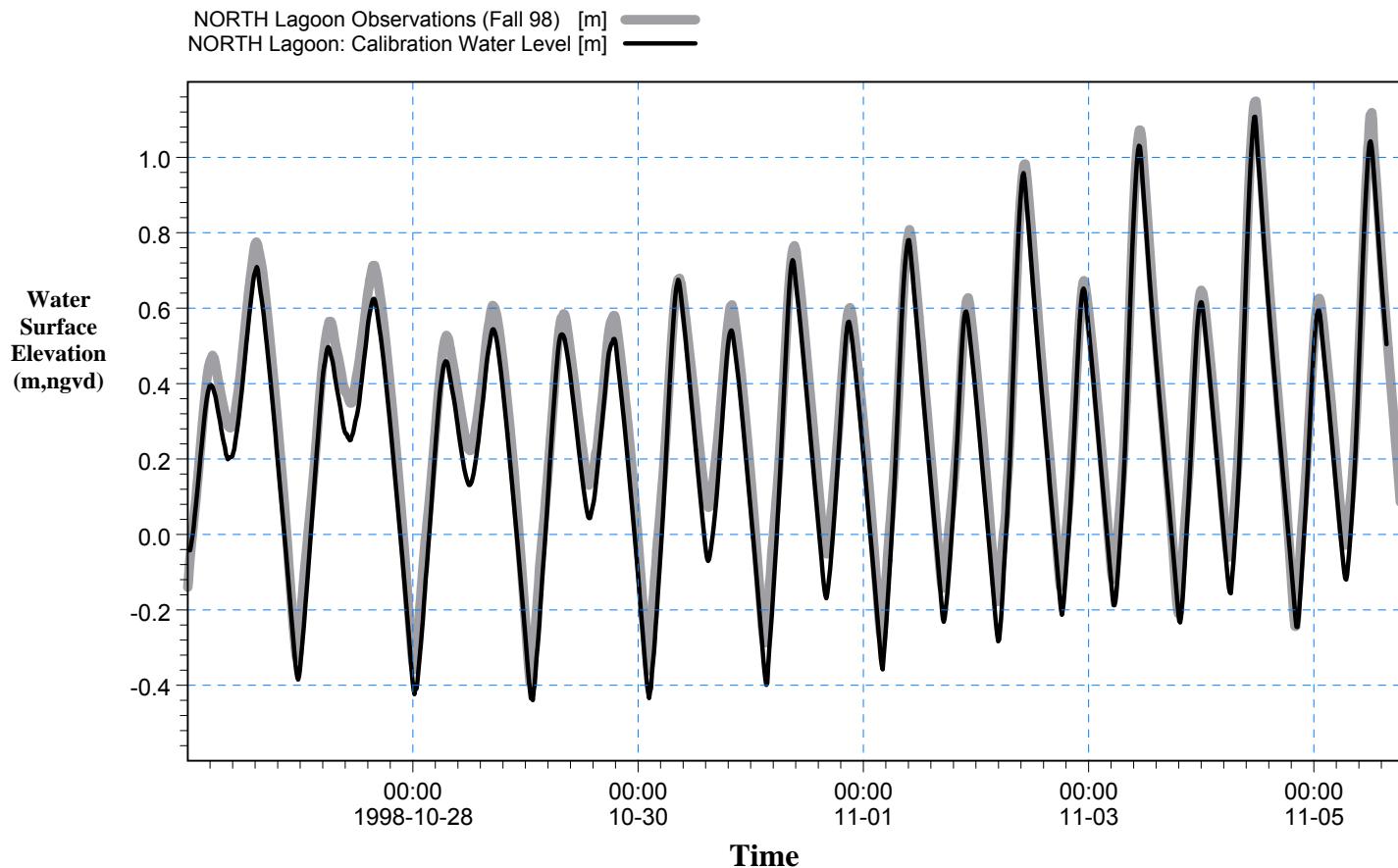


Figure 4.6b: Calibrated and Observed Water Levels: South Lagoon

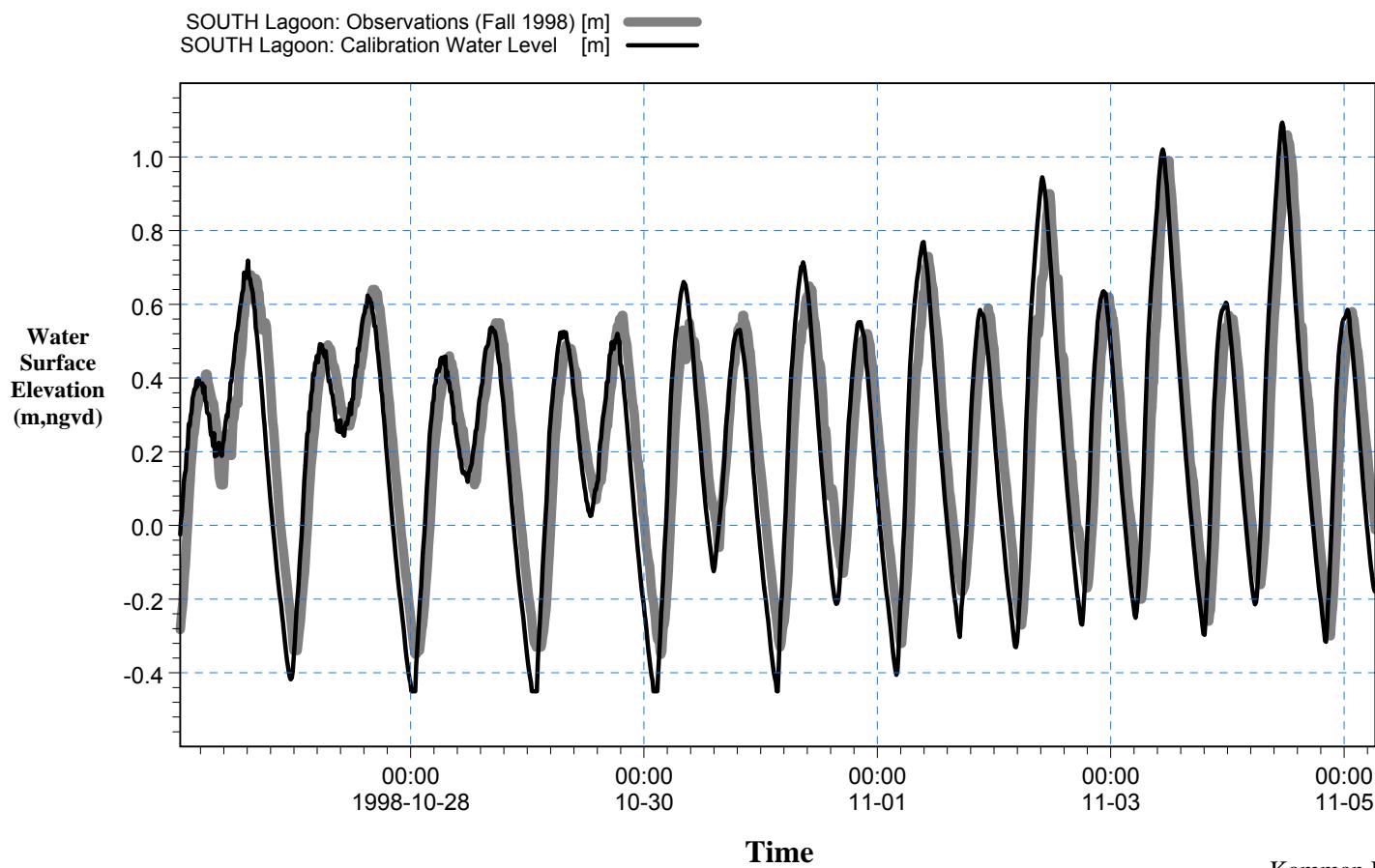
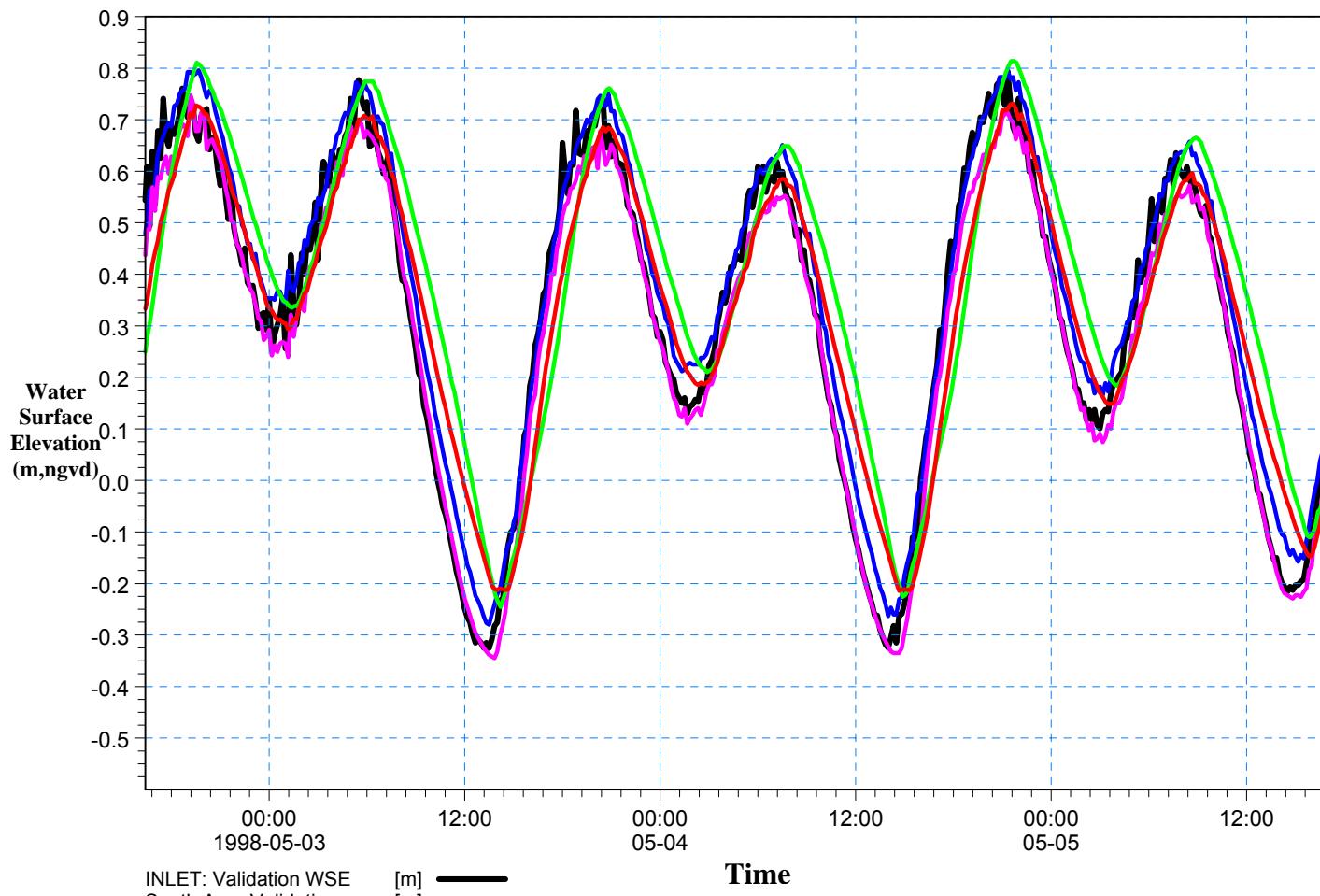


Figure 4.7: Validation Water Levels: Observed and Predicted

INLET WSE: Spring Observations (NGVD) [m] —————
 South Arm WSE: Spring Observations (NGVD) [m] —————
 Bolinas Channel WSE: Spring Observations (NGVD) [m] —————
 "North WSE: Spring Observations (NGVD)" [m] —————
 "South WSE: Spring Observations (NGVD)" [m] —————

4.7a: Observed Values



4.7b: Predicted Values

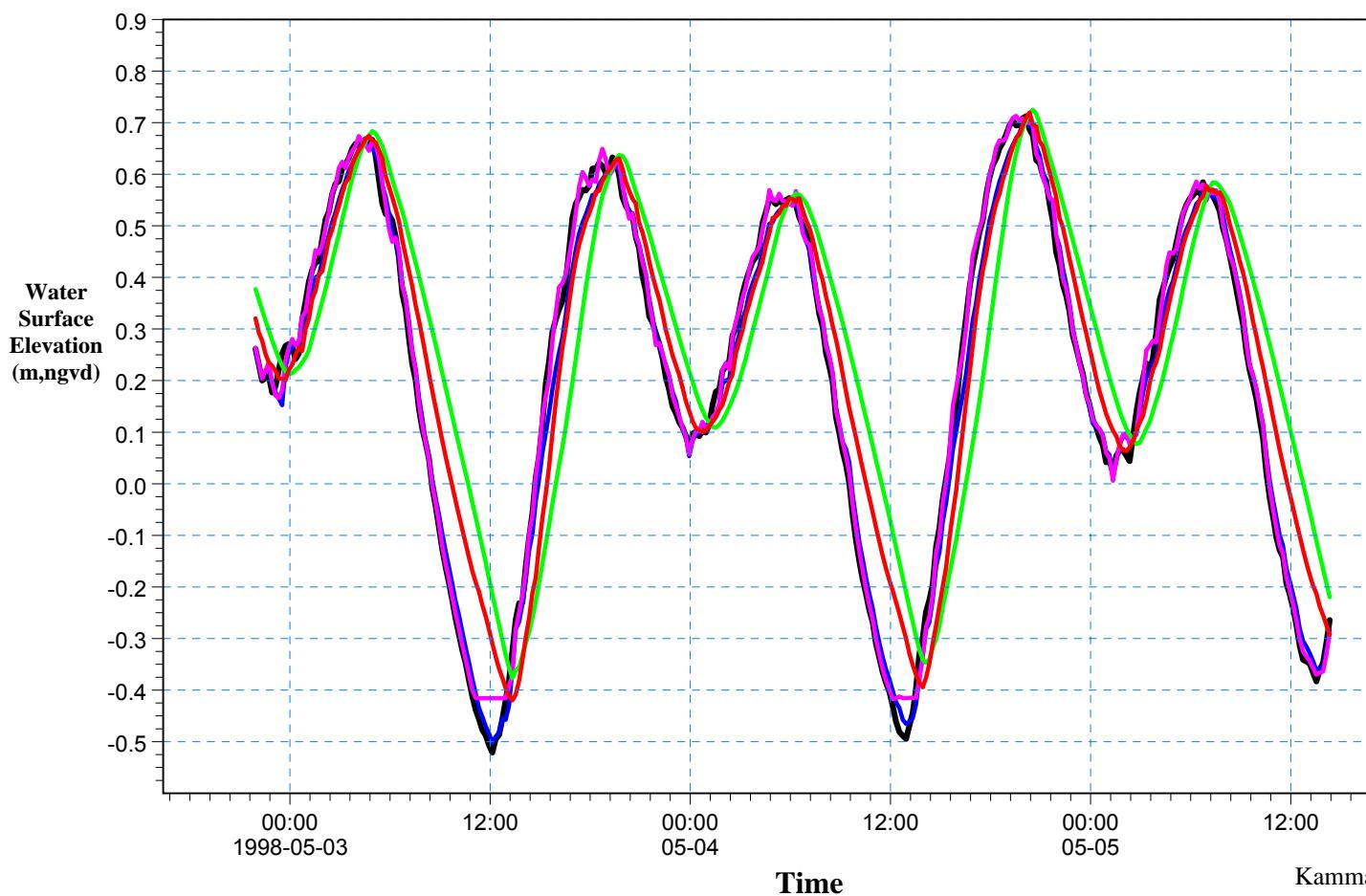
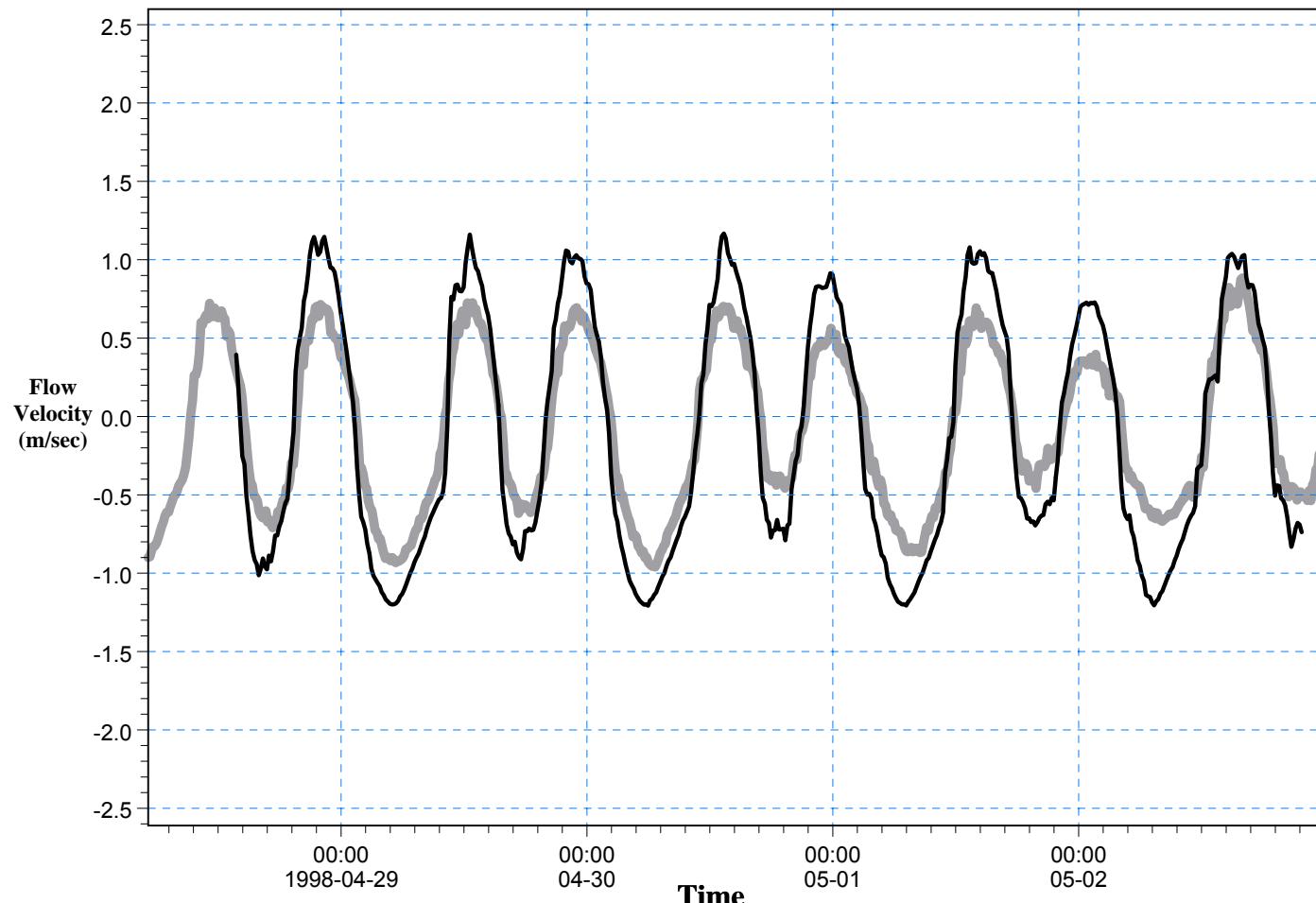


Figure 4.8: Validation Flow Velocities: South Arm Channel

South Arm: Observations X-Velocity (Spring 1998) [m/s] —————
 South Arm: Spring Validation X-Vel. [m/s] —————

Figure 4.8a: Velocities in X-Direction



South Arm: Observations Y-Velocity (Spring 1998) [m/s] —————
 South Arm: Spring Validation Y-Vel. [m/s] —————

Figure 4.8a: Velocities in Y-Direction

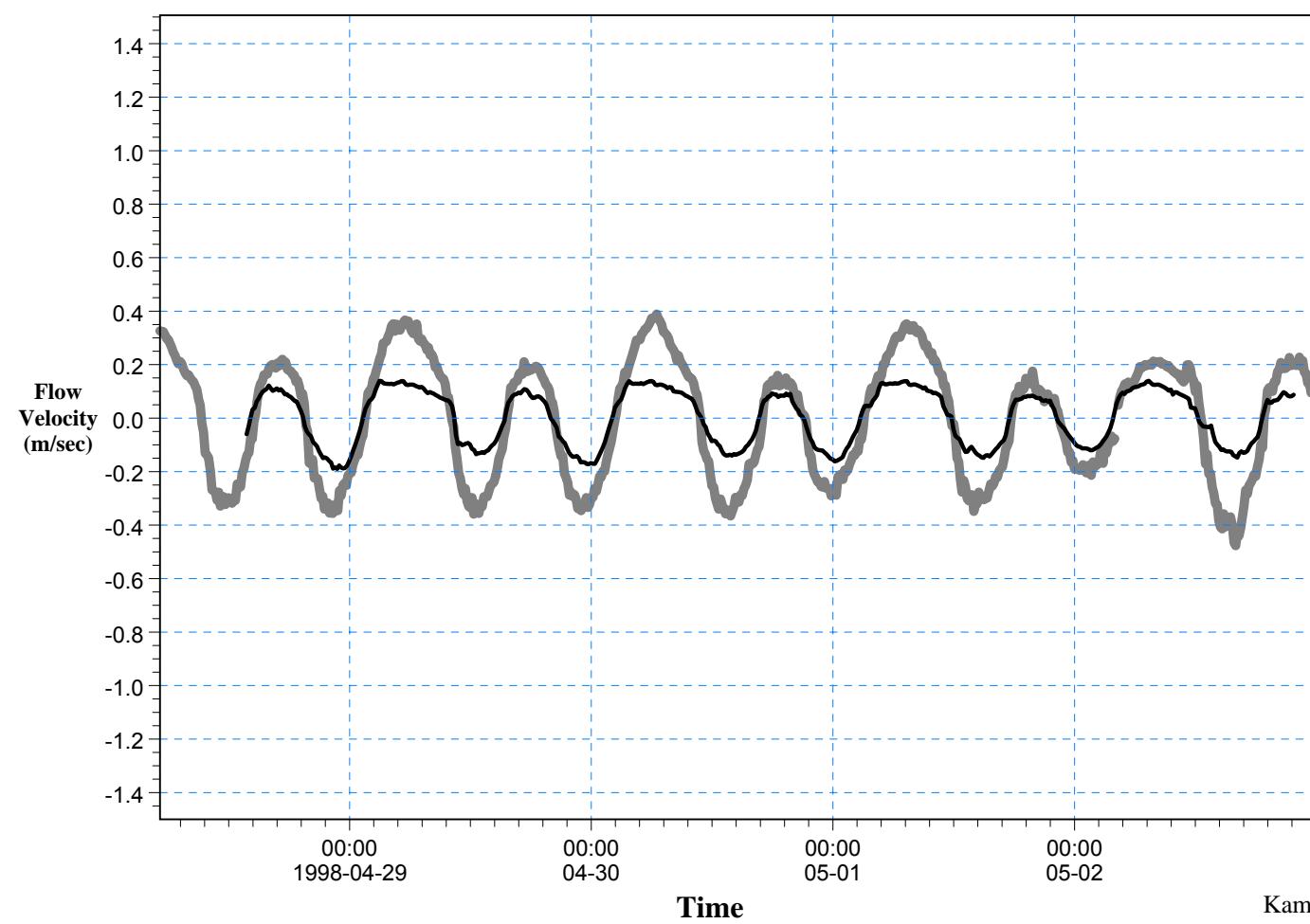
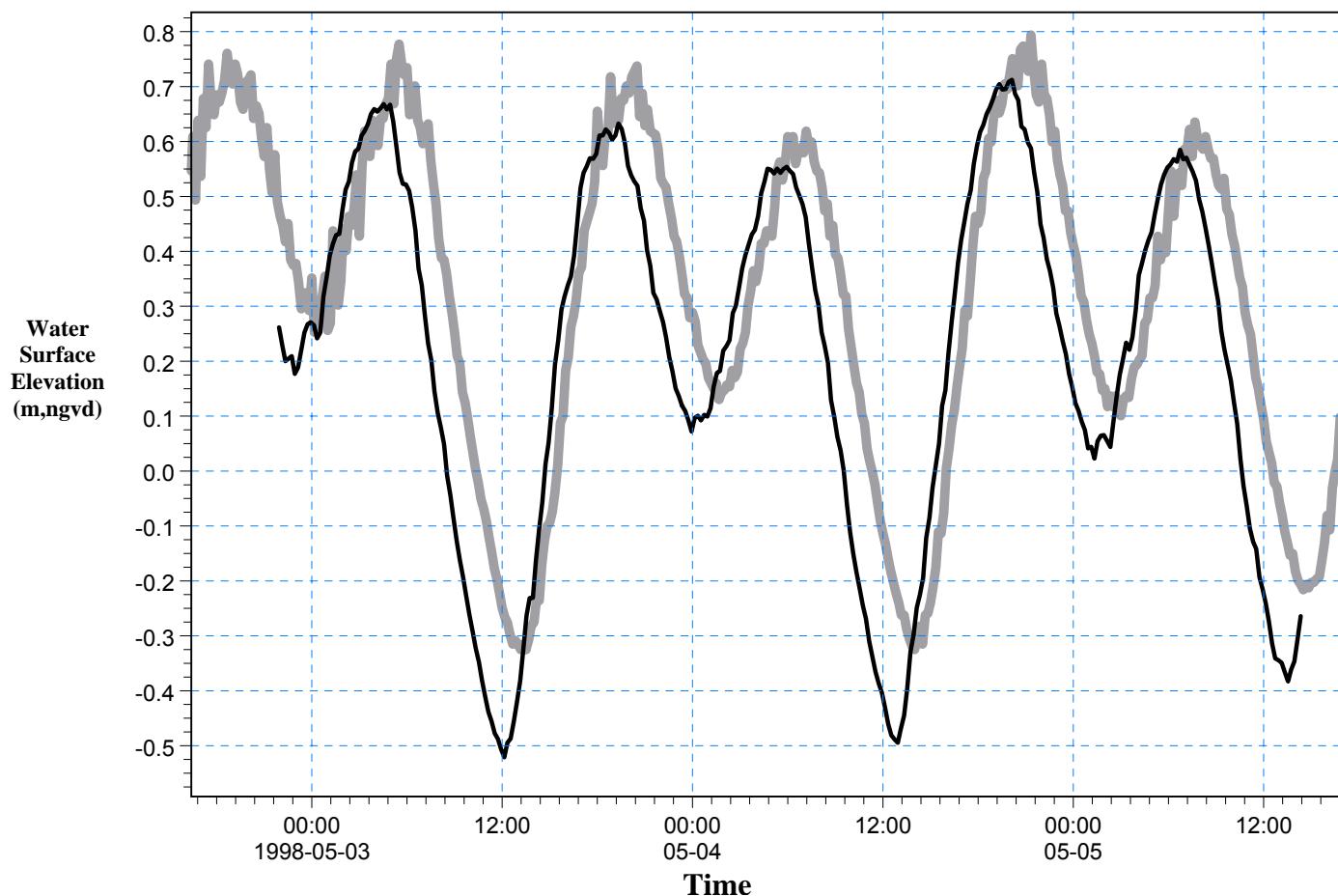


Figure 4.9: Validation Water Levels: West Lagoon

INLET WSE: Spring Observations (NGVD) [m] —————
INLET: Validation WSE [m] —————

Figure 4.9a: Observed and Predicted Water Levels: Inlet Channel



South Arm WSE: Spring Observations (NGVD) [m]
South Arm: Validation [m]

Figure 4.9b: Observed and Predicted Water Levels: South Arm Channel

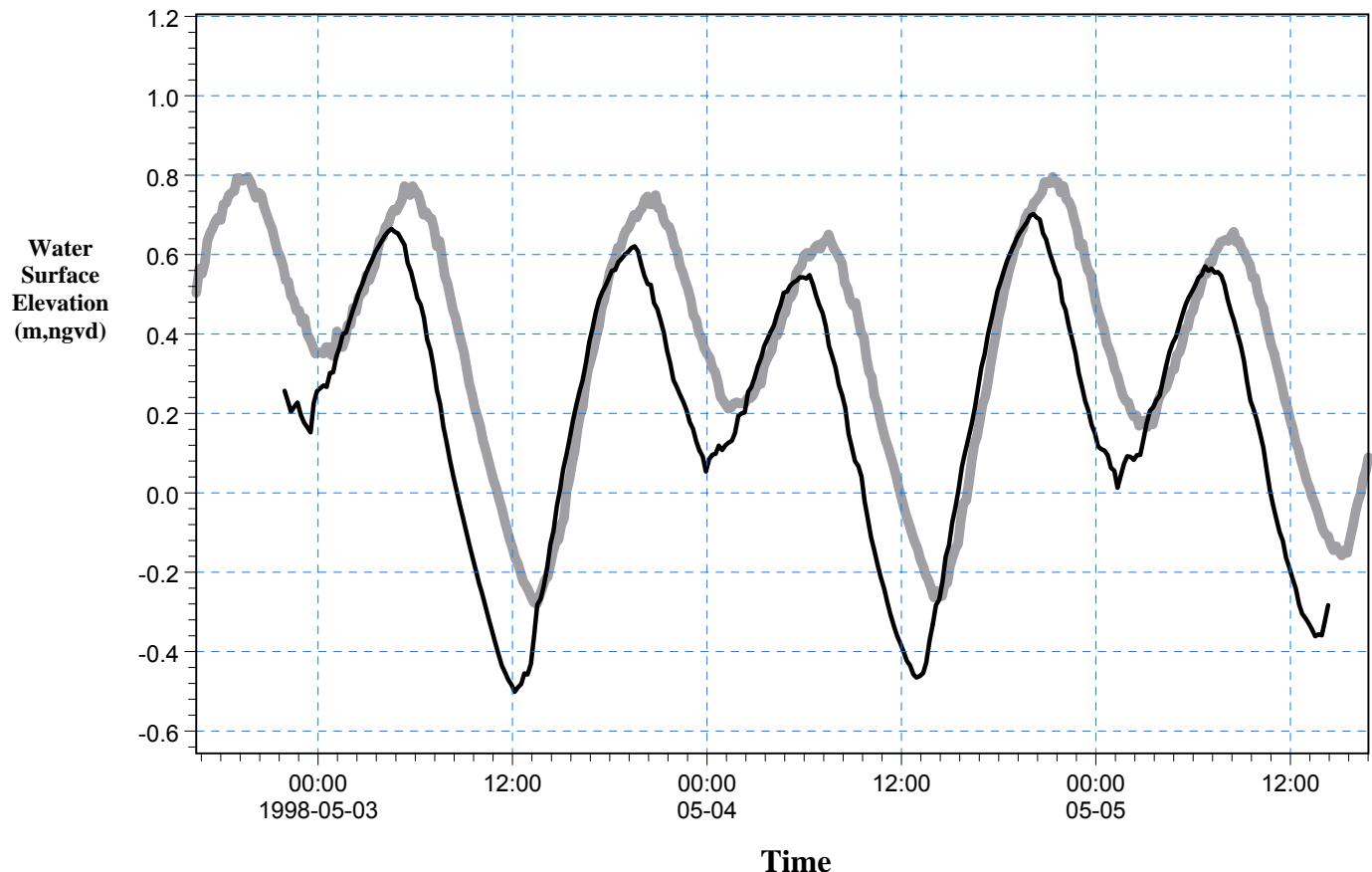
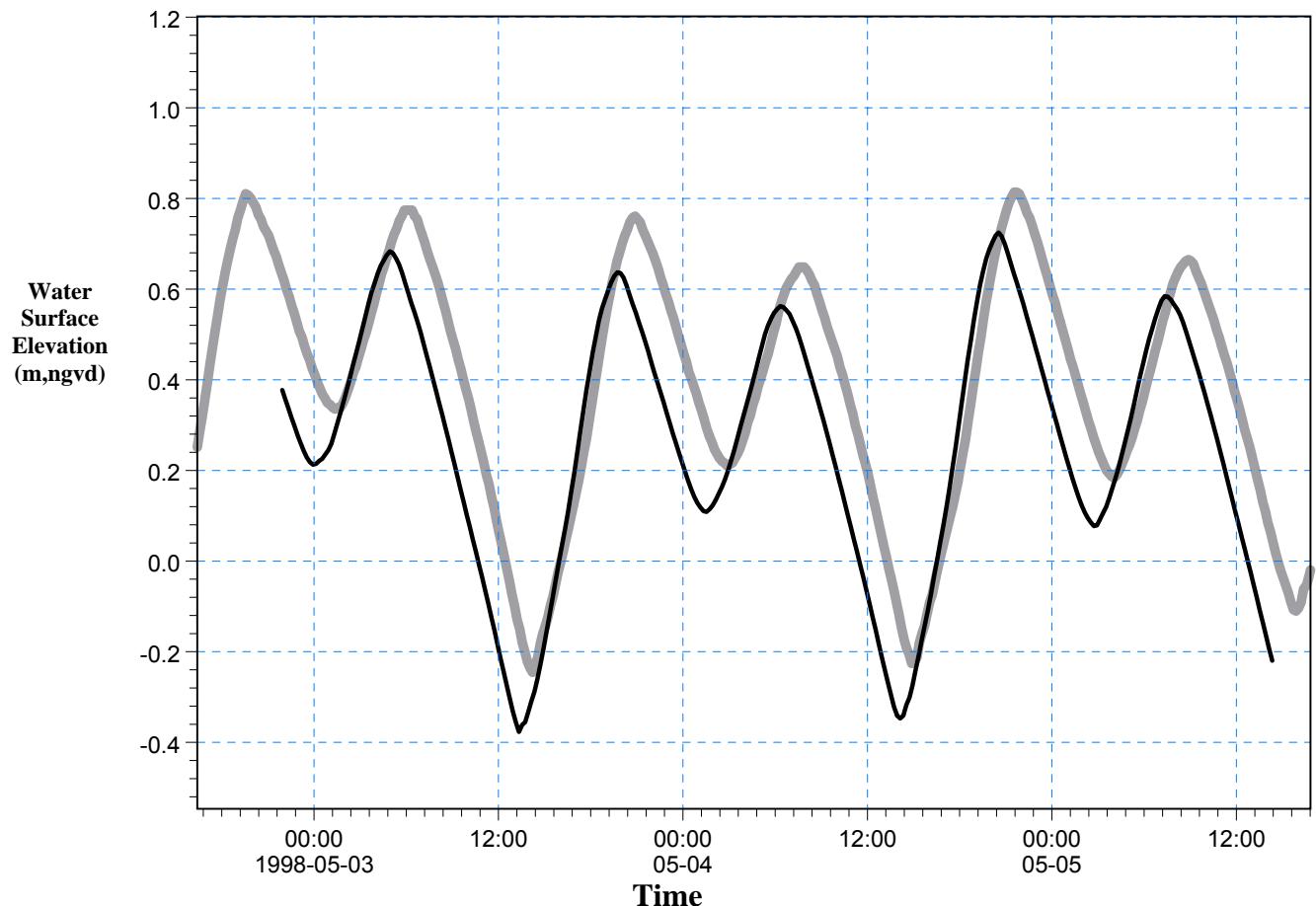


Figure 4.10: Validation Water Levels: East Lagoon

"North WSE: Spring Observations (NGVD)" [m] — "North: Validation WSE" [m] —

Figure 4.10a: Observed and Predicted Water Levels: North Lagoon



"South WSE: Spring Observations (NGVD)" [m] — "South: Validation WSE" [m] —

Figure 4.10b: Observed and Predicted Water Levels: South Lagoon

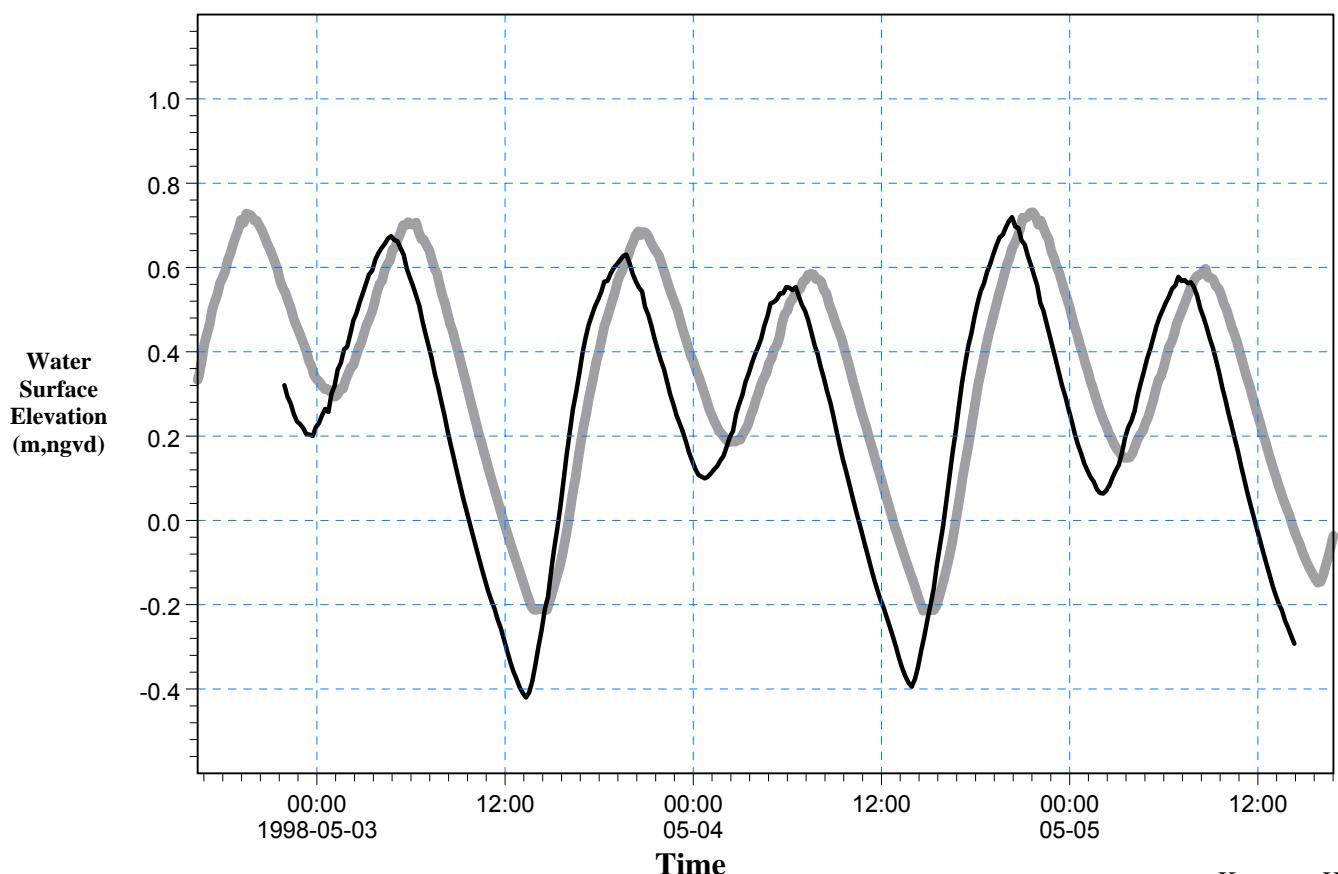
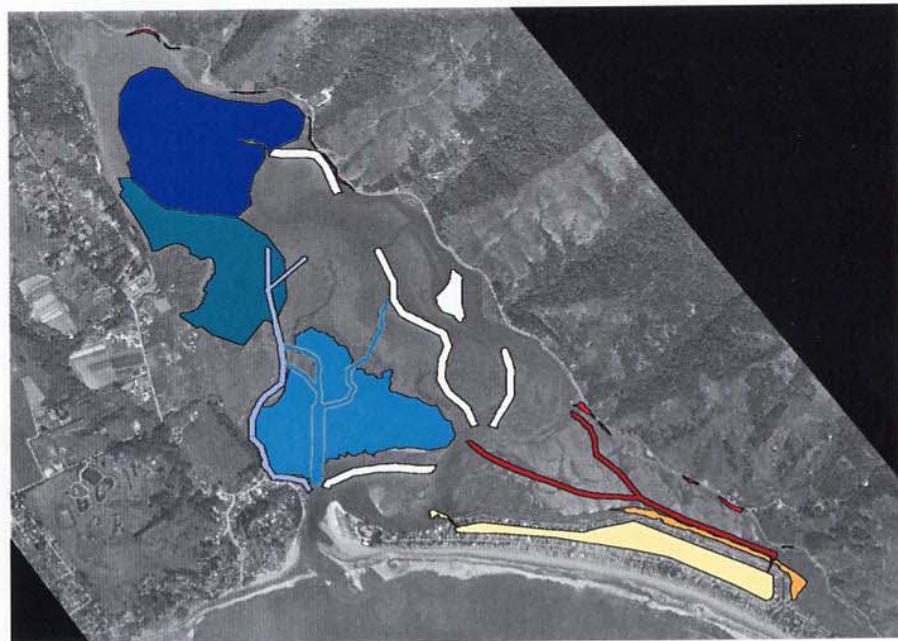


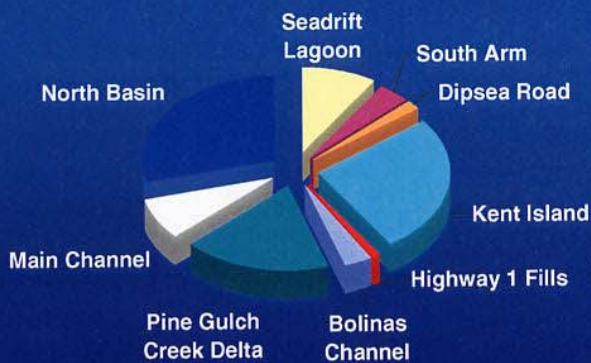
Figure 5.1: Restoration Components

Calculated Surface Area and Dredge Volumes for Alternative Components

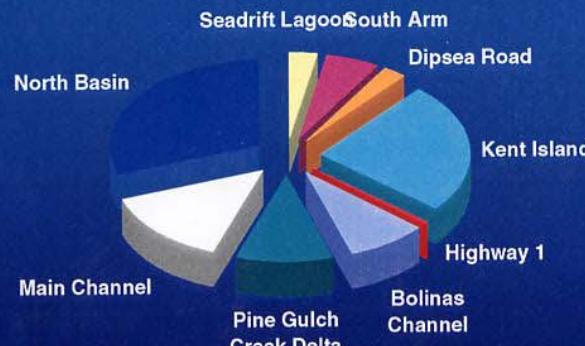
Component	Surface Area acres	Volume yds ³
Bolinas Channel	15.59	130,799
Pine Gulch Creek Delta	86.36	158,652
Dipsea Road	7.97	36,828
Highway 1 Fills	3.25	4,828
Kent Island	124.09	376,729
Seadrift Lagoon	43.47	44,958
South Arm Channel	17.58	89,430
Main Channel	37.49	216,241
North Basin	136.11	458,538
Totals	471.92	1,517,002



Lagoon Bottom Surface Area Affected by Alternative Components



Sediment Volume Removal Distribution For Alternative Components

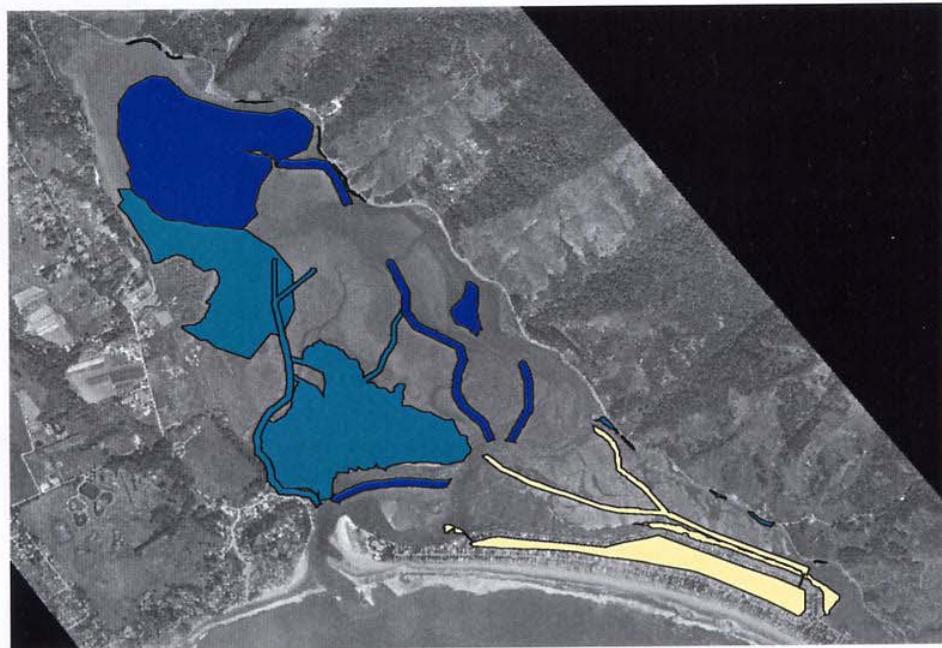


Source: J. Winkleman, HEEP Briefing, 3/01

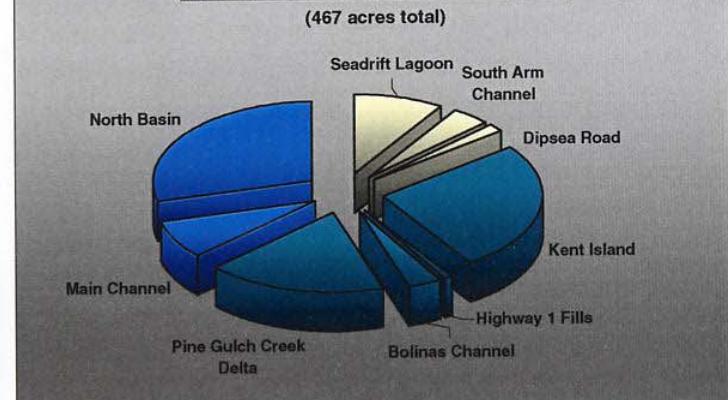
Figure 5.2: Restoration Alternatives

Alternative Dredge Volume and Foot Print Area

Alternative	Surface Area acres	Dredge Volume yds ³
North	173.60	674,778
Central	229.30	671,008
South	69.02	171,216
North and Central	402.90	1,345,786
North and South	242.62	845,995
Central and South	298.32	842,224
North, Central, and South	471.92	1,517,002

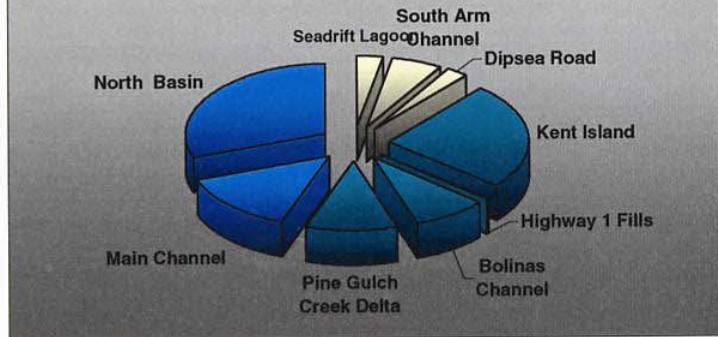


Alternative Foot Print Surface Areas



Alternative Dredge Volume

(1.52 million cubic yards total)



Source: J. Winkleman, HEEP Briefing, 3/01

Figure 5.3: Model Bathymetry: Current Conditions Scenario

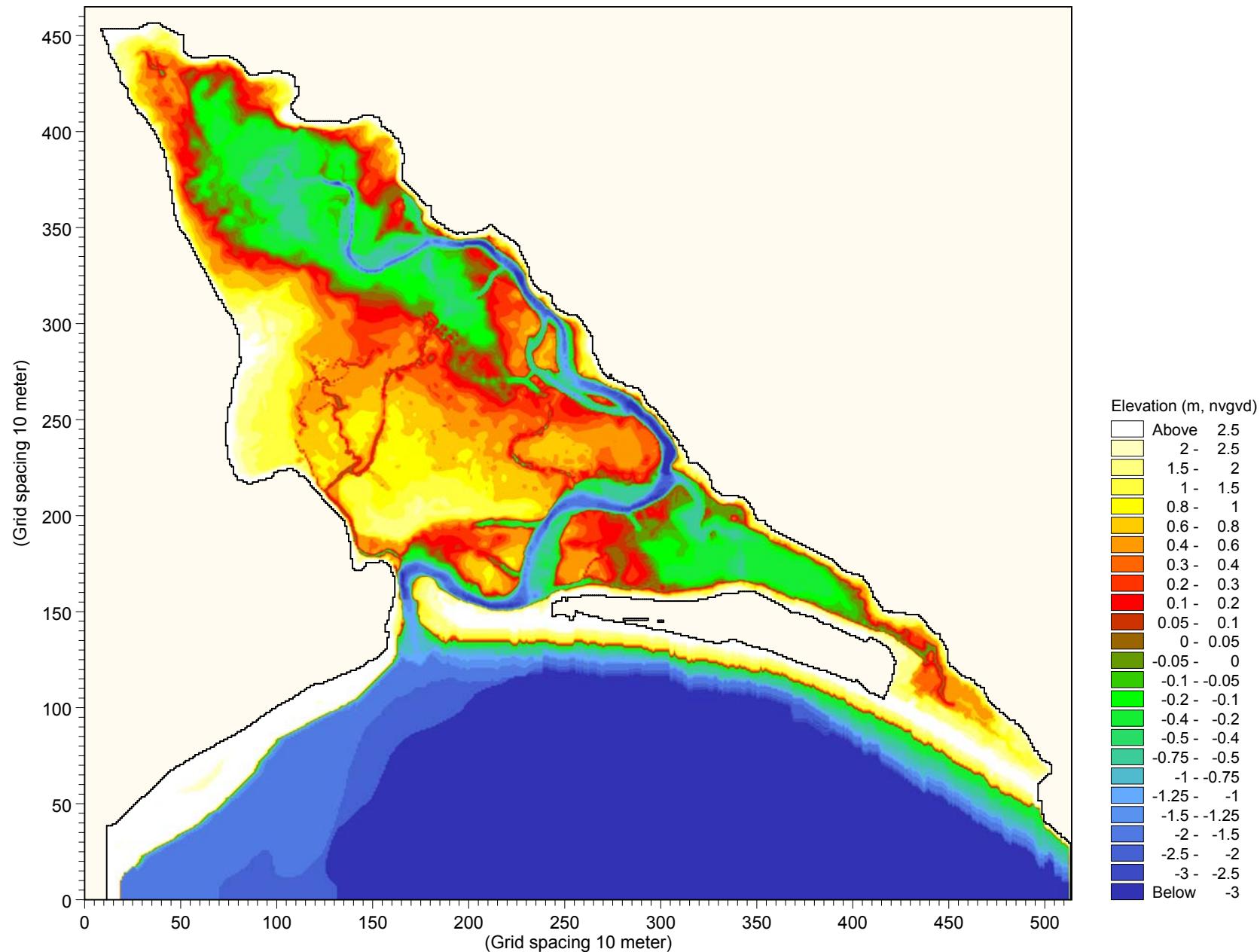


Figure 5.4: Model Bathymetry: Full Construction Scenario

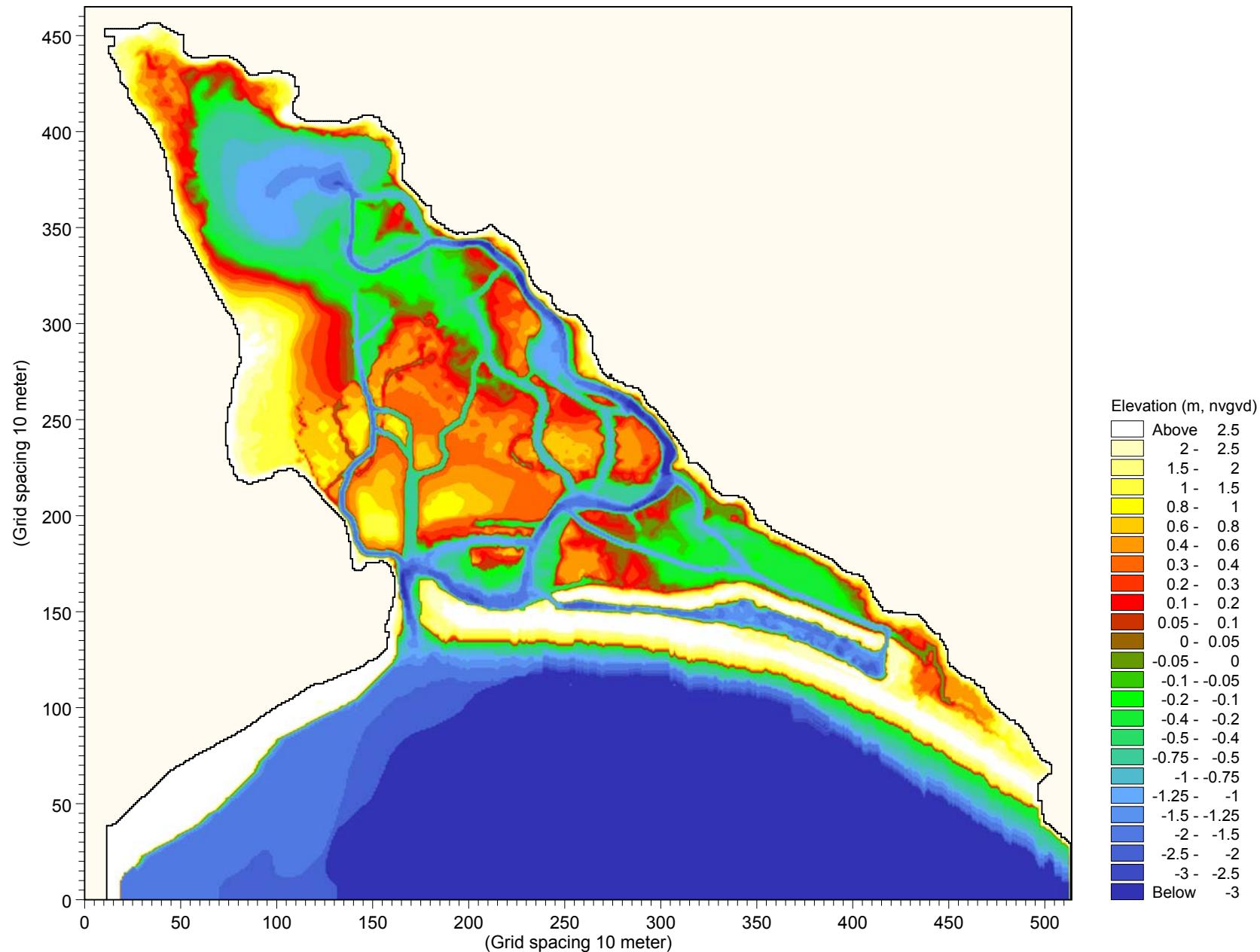


Figure 5.5: Model Bathymetry: North & Central Scenario

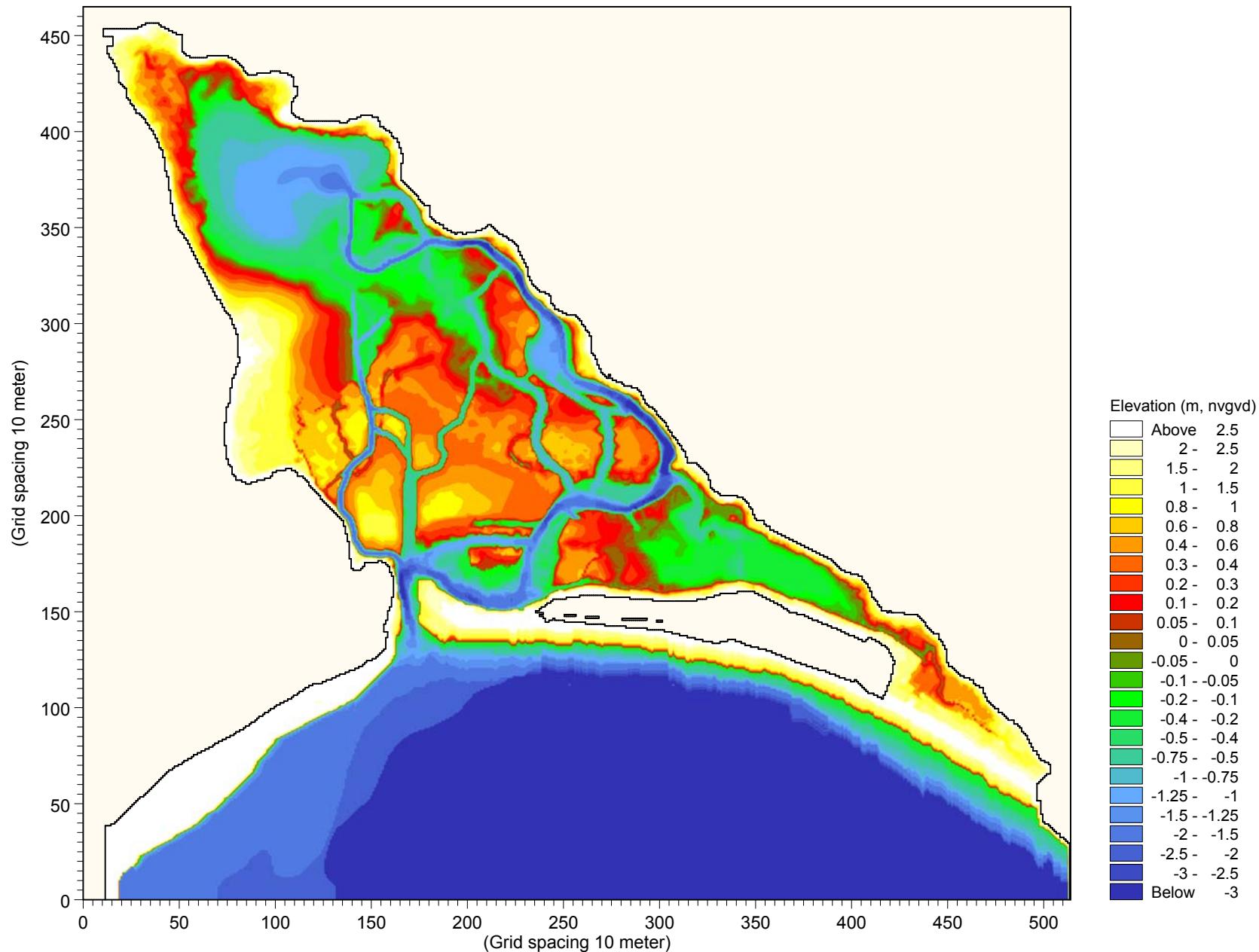


Figure 5.6: Model Bathymetry: North & South Scenario

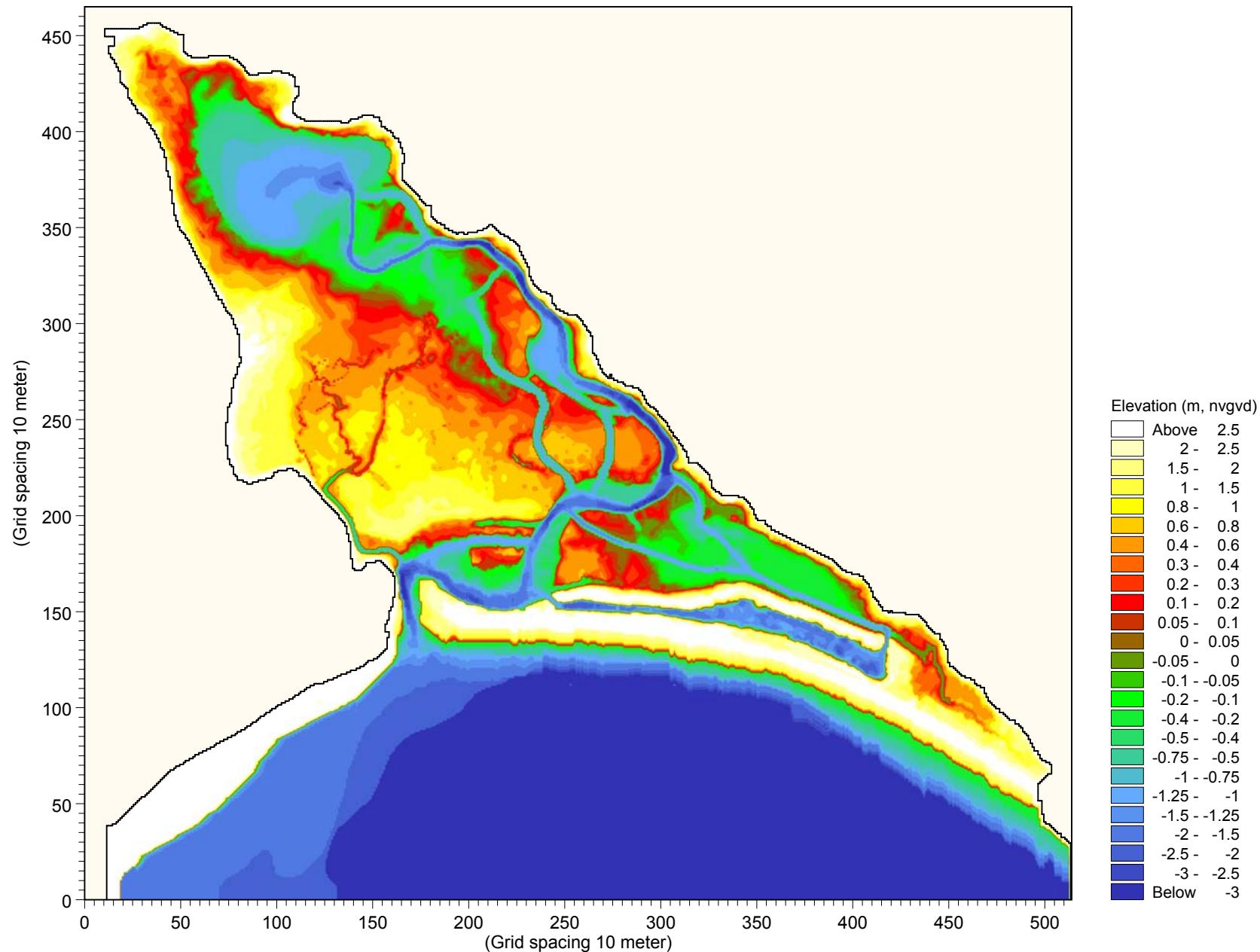
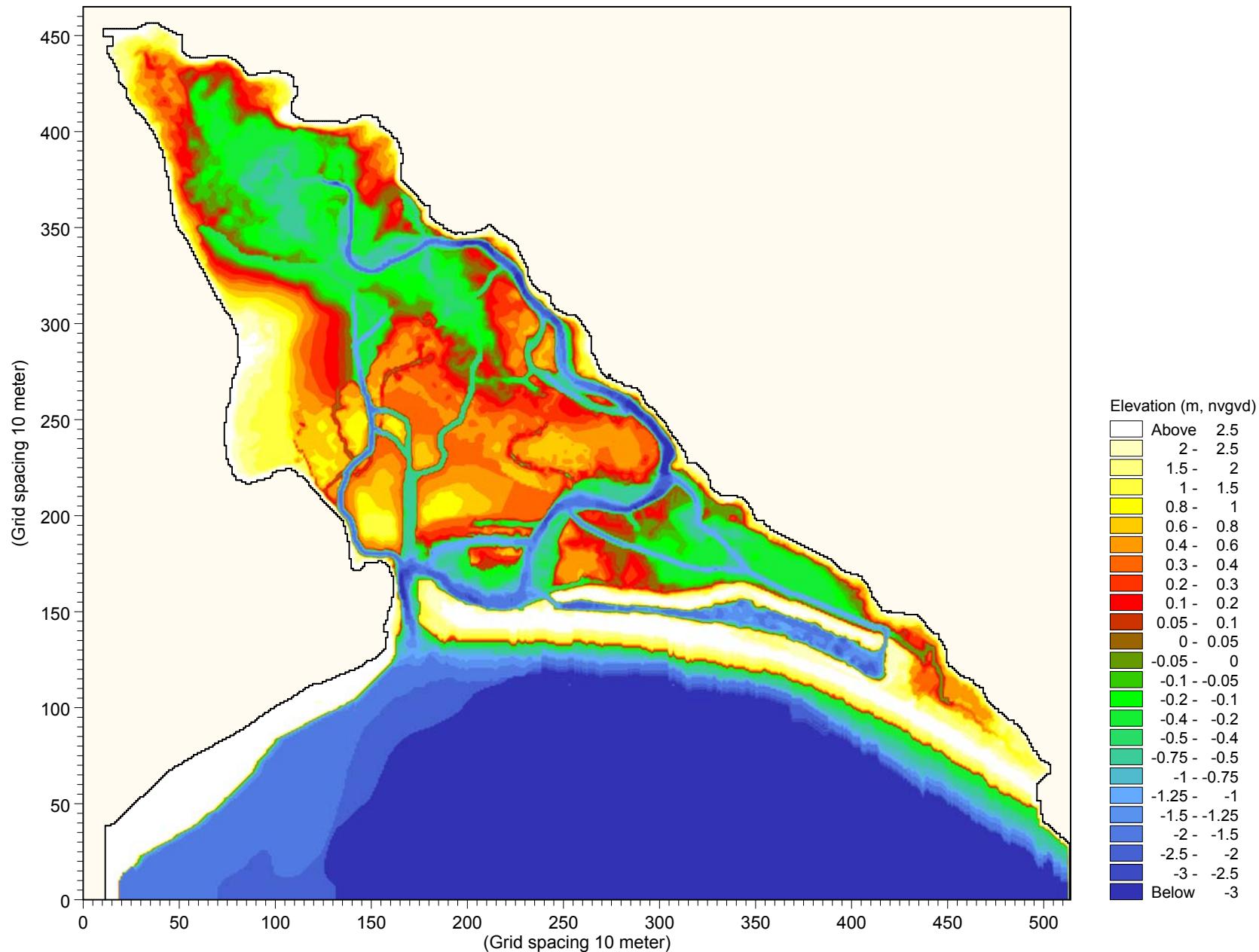


Figure 5.7: Model Bathymetry: Central & South Scenario



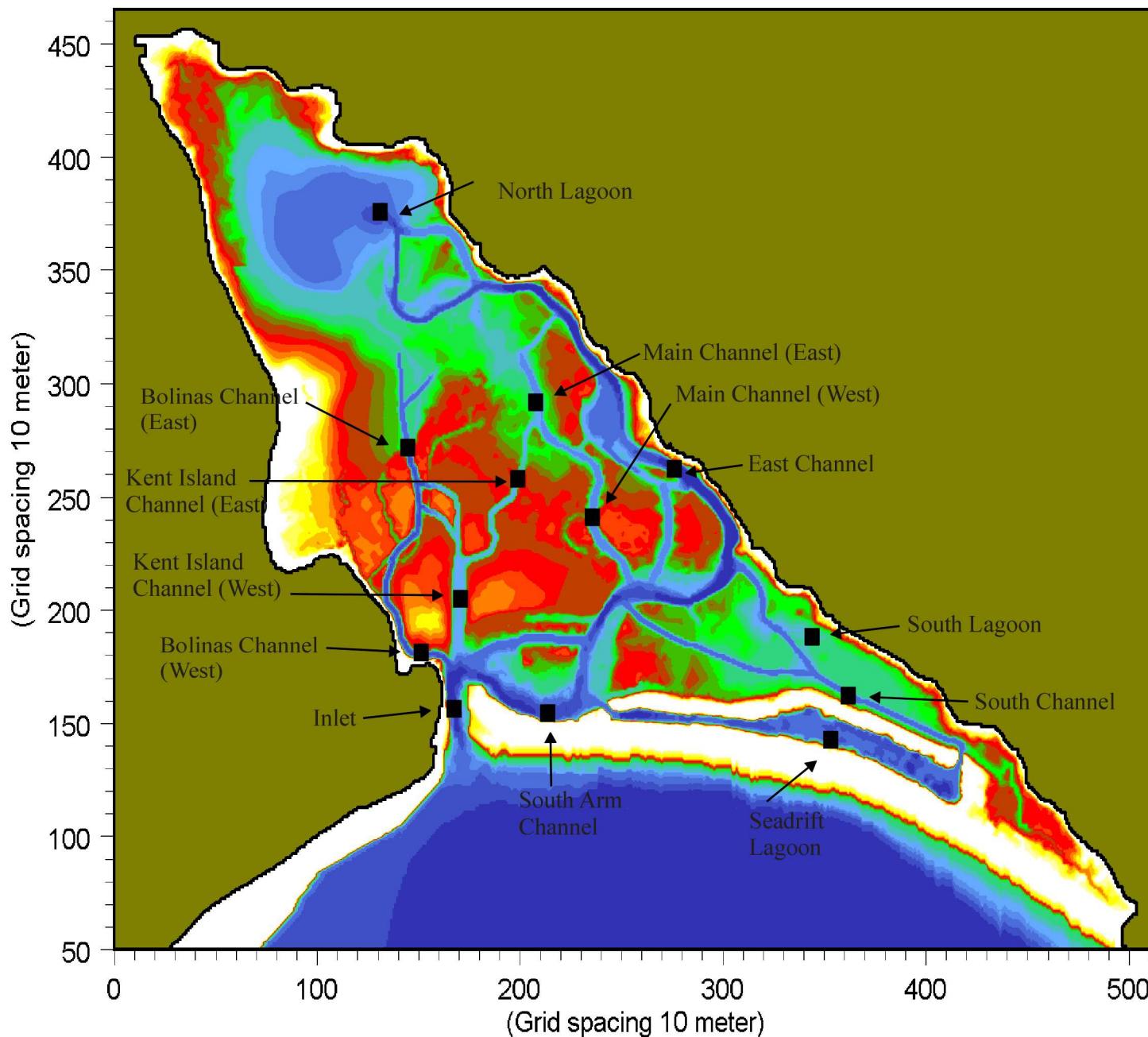
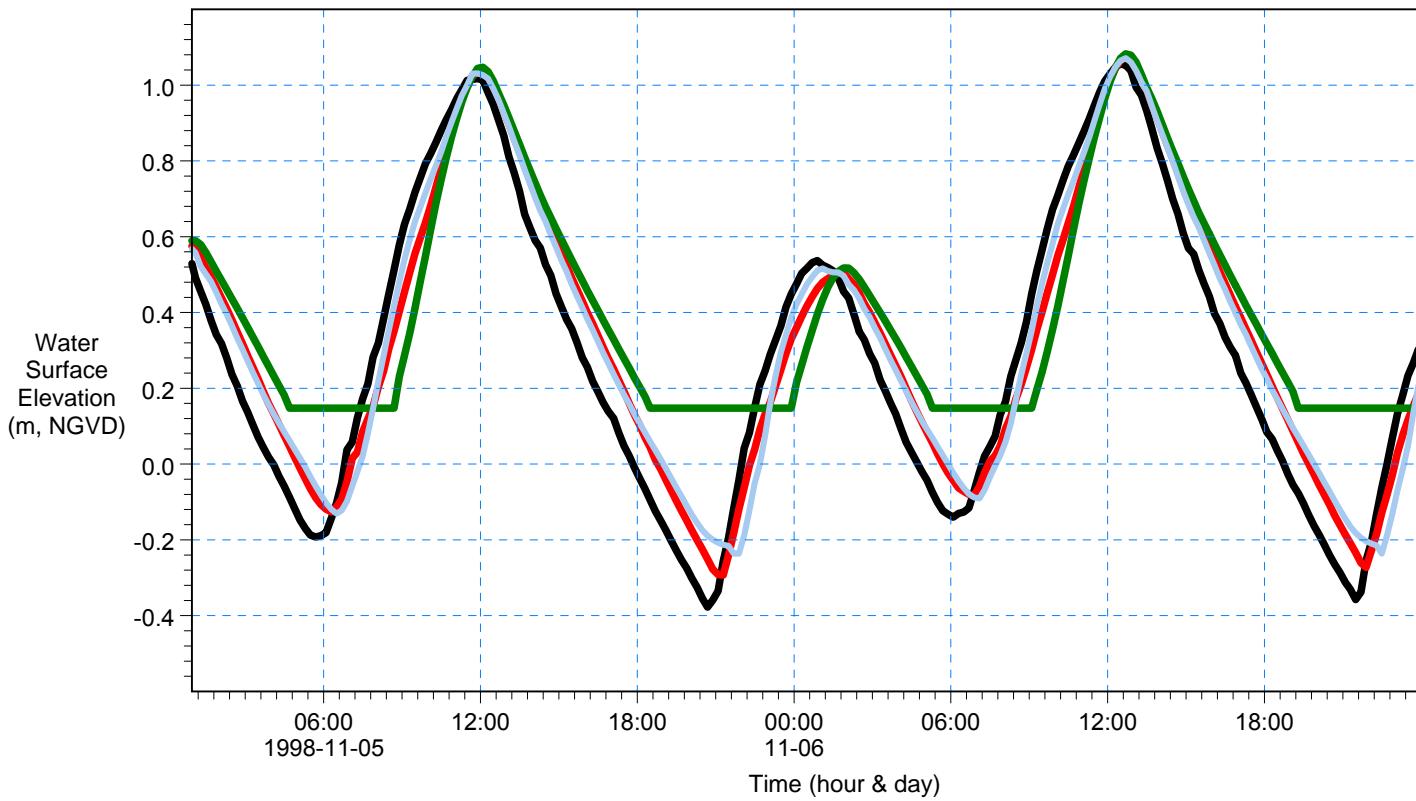


Figure 6.1: □
Water Level and Velocity □
Evaluation Points

Figure 6.2a: Predicted Tidal Amplitudes in Bolinas Lagoon: 1998 Scenario

South Arm Channel: 1998 WSEs [m] —
 East Channel: 1998 WSEs [m] —
 North Lagoon: 1998 WSEs [m] —
 South Channel: 1998 WSEs [m] —

6.2a.1: Spring Tidal Cycle



South Arm Channel: (1998) WSEs [neap] [m] —
 East Channel: (1998) WSEs [neap] [m] —
 North Lagoon: (1998) WSEs [neap] [m] —
 South Channel: (1998) WSEs [neap] [m] —

6.2a.2: Neap Tidal Cycle

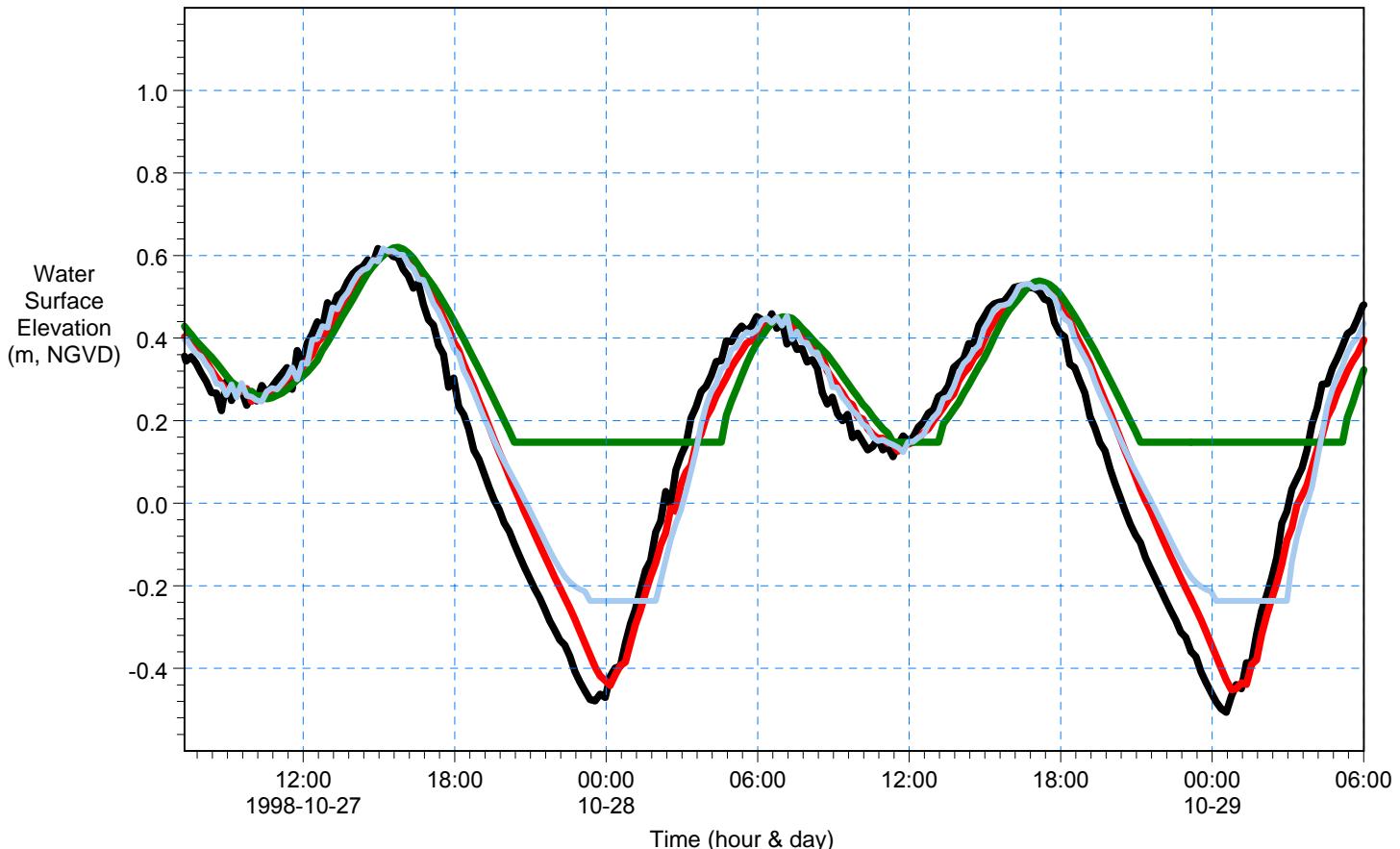
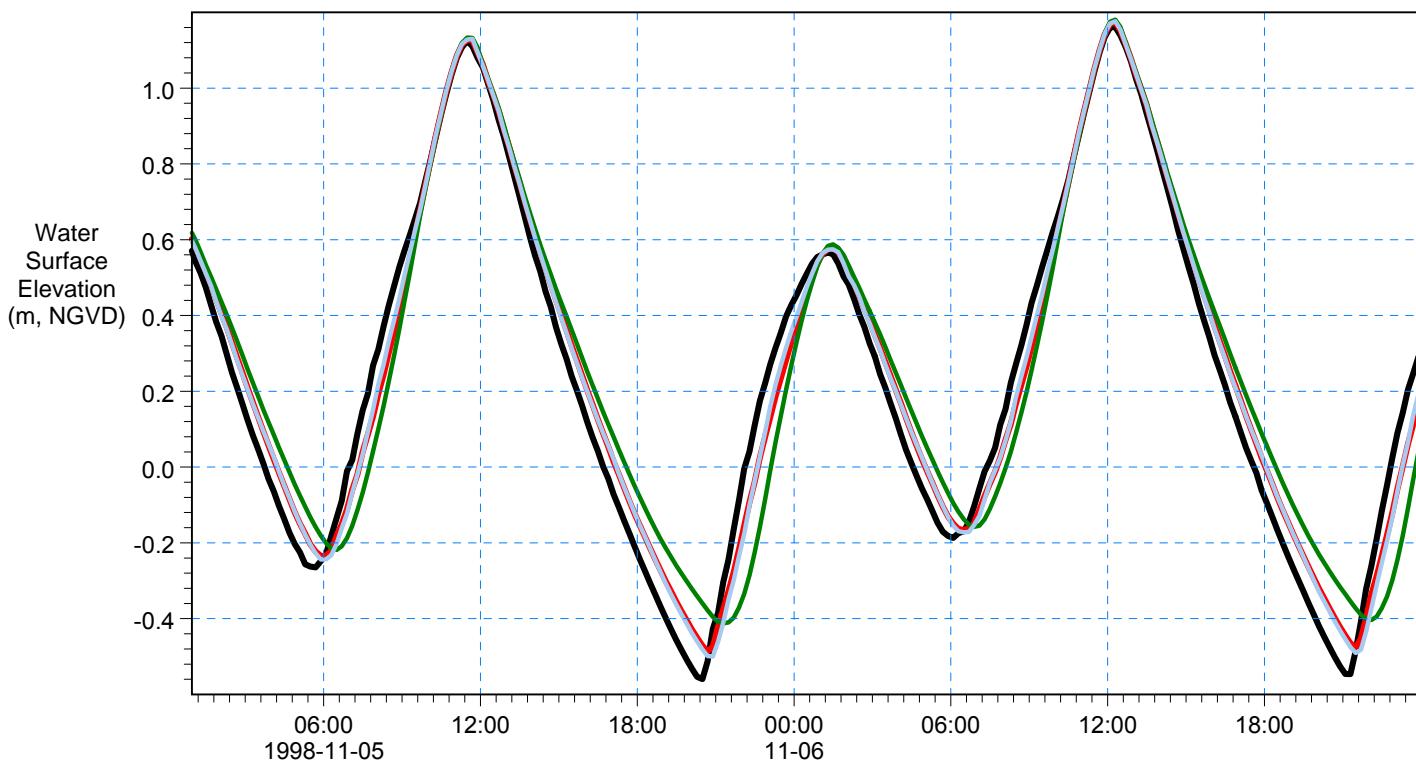


Figure 6.2b: Predicted Tidal Amplitudes in Bolinas Lagoon: Full Construction Scenario

South Arm: Full Construction WSE [m] ——————
 East Channel: Full Construction WSE [m] ——————
 North Lagoon: Full Construction WSE [m] ——————
 South Channel: Full Construction WSE [m] ——————

6.2b.1: Spring Tidal Cycle



South Arm Channel: Full Constr. neap WSEs [m] ——————
 East Channel: Full Constr. neap WSEs [m] ——————
 North Lagoon: Full Constr. neap WSEs [m] ——————
 South Channel: Full Constr. neap WSEs [m] ——————

6.2b.2: Neap Tidal Cycle

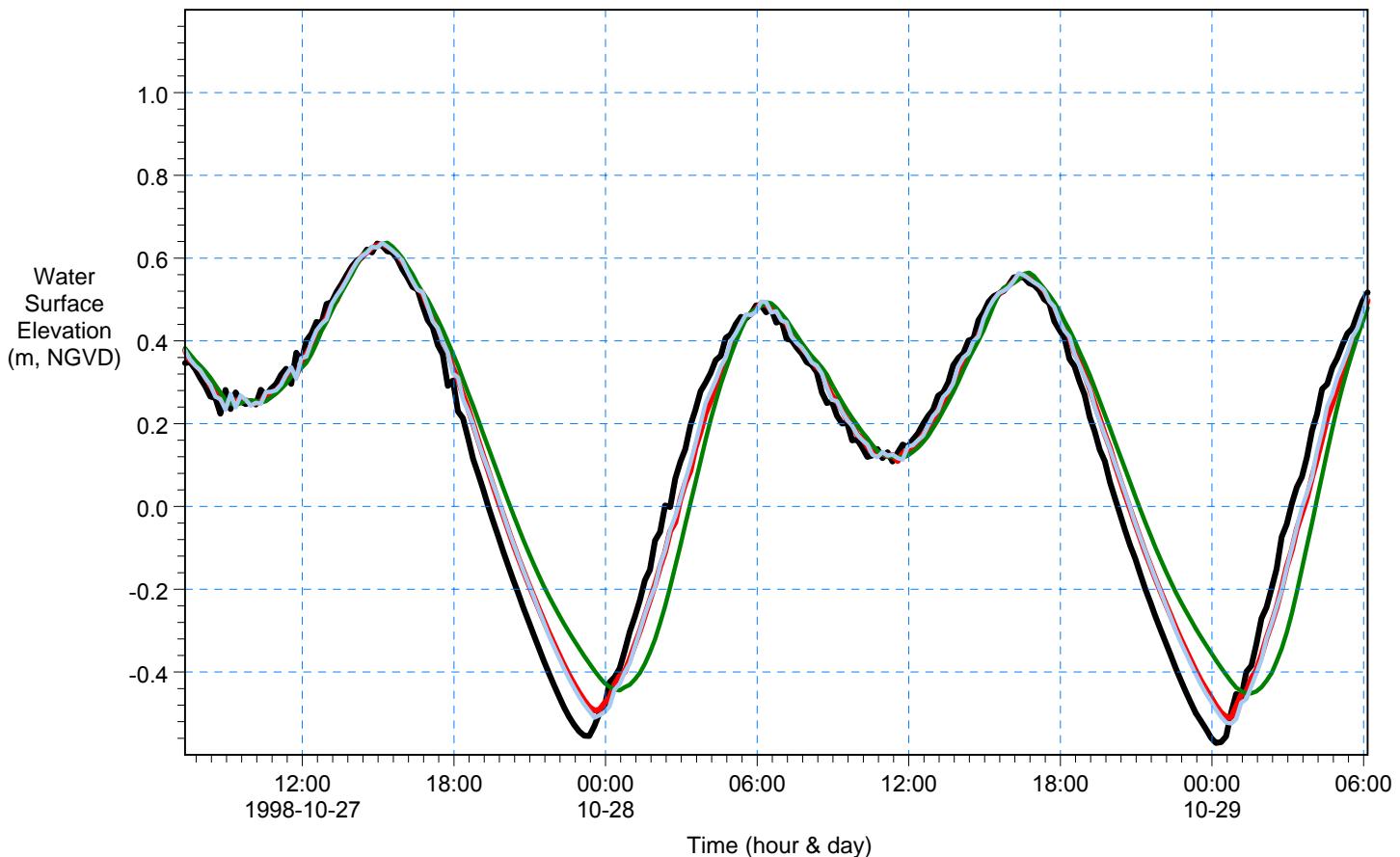
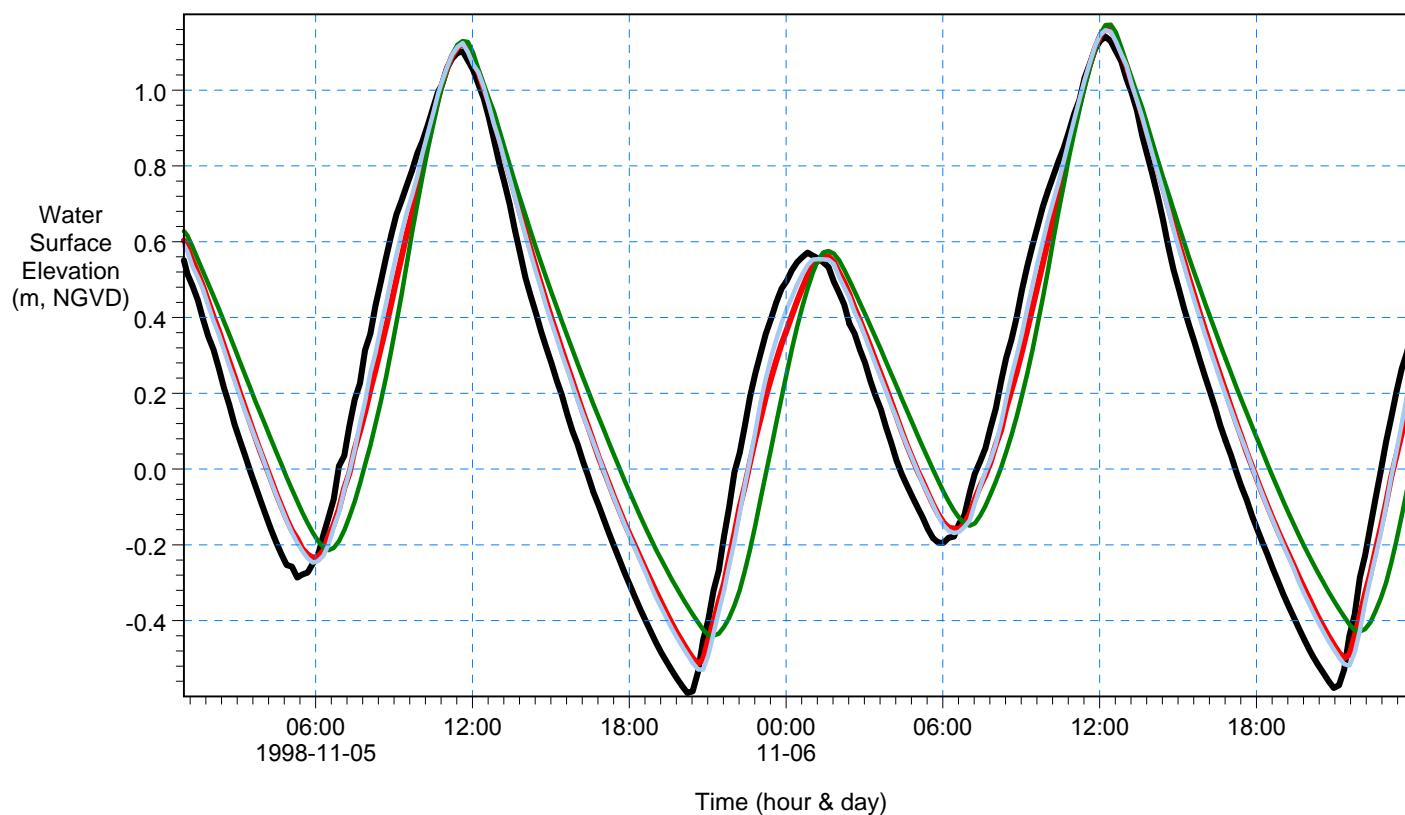


Figure 6.2c: Predicted Tidal Amplitudes in Bolinas Lagoon: North & South Scenario

South Arm : NO & SO WSE [m] ——————
 East Channel: NO & SO WSE [m] ——————
 North Lagoon: NO & SO WSE [m] ——————
 South Channel: NO & SO WSE [m] ——————

6.2c.1: Spring Tidal Cycle



South Arm Channel: No. & So. neap WSEs [m] ——————
 East Channel: No. & So. neap WSEs [m] ——————
 North Lagoon: No. & So. neap WSEs [m] ——————
 South Channel: No. & So. neap WSEs [m] ——————

6.2c.2: Neap Tidal Cycle

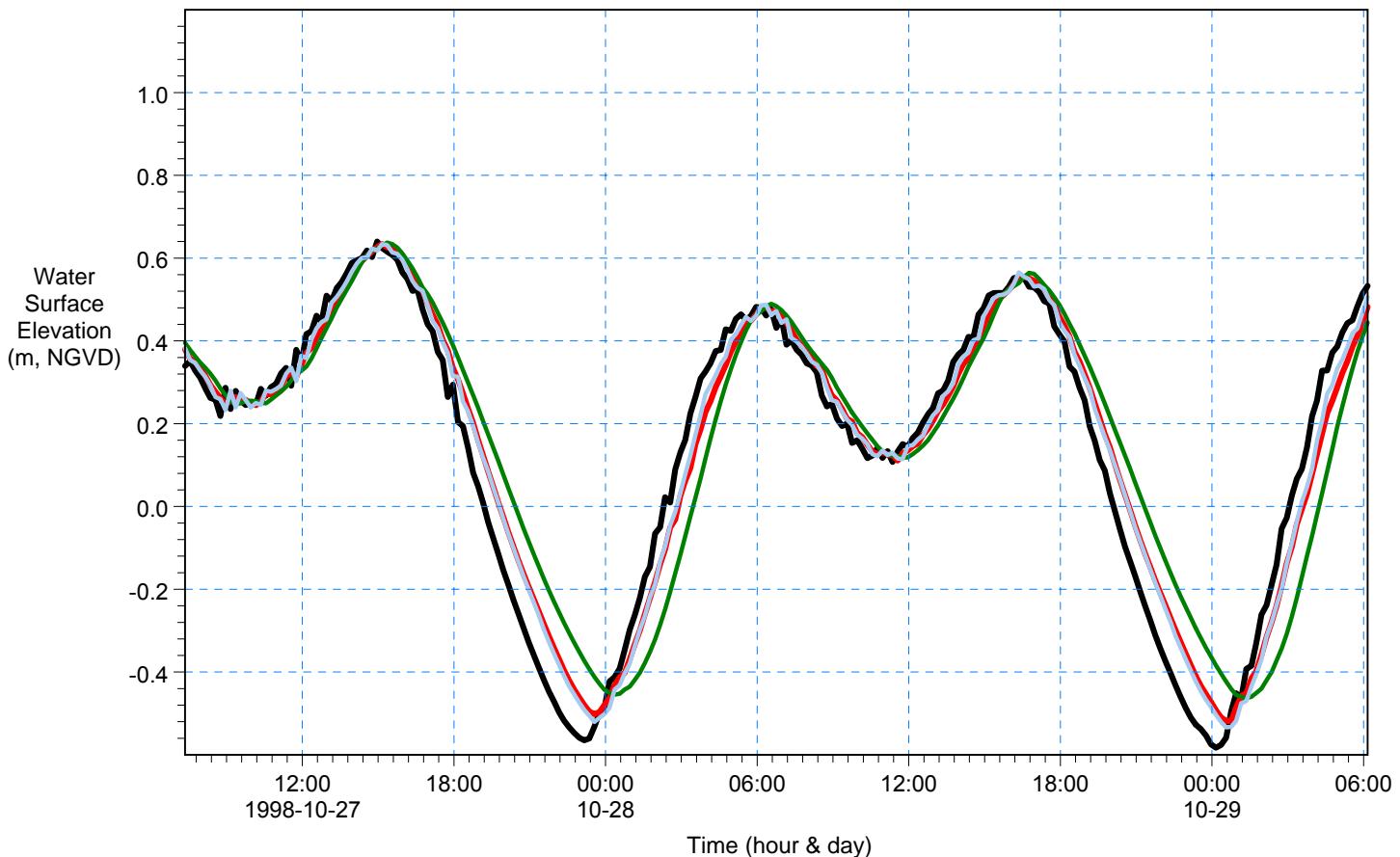
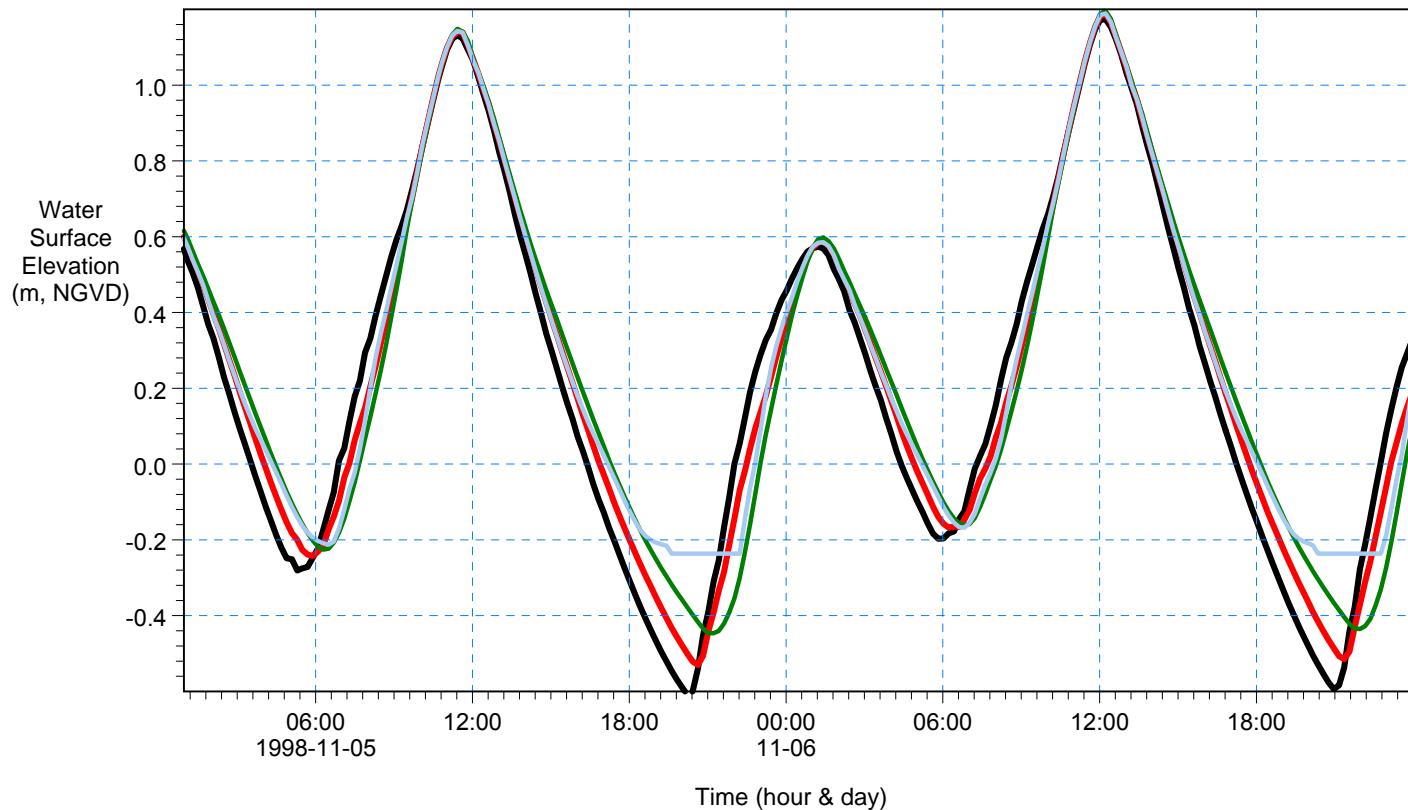


Figure 6.2d: Predicted Tidal Amplitudes in Bolinas Lagoon: North & Central Scenario

South Arm Channel: NO & CE WSEs [m] —————
 East Channel: NO & CE WSEs [m] —————
 North Lagoon: NO & CE WSEs [m] —————
 South Channel: NO & CE WSEs [m] —————

6.2d.1: Spring Tidal Cycle



South Arm Channel: No & CE neap WSEs [m] —————
 East Channel: No & CE neap WSEs [m] —————
 North Lagoon: No & CE neap WSEs [m] —————
 South Channel: No & CE neap WSEs [m] —————

6.2d.2: Neap Tidal Cycle

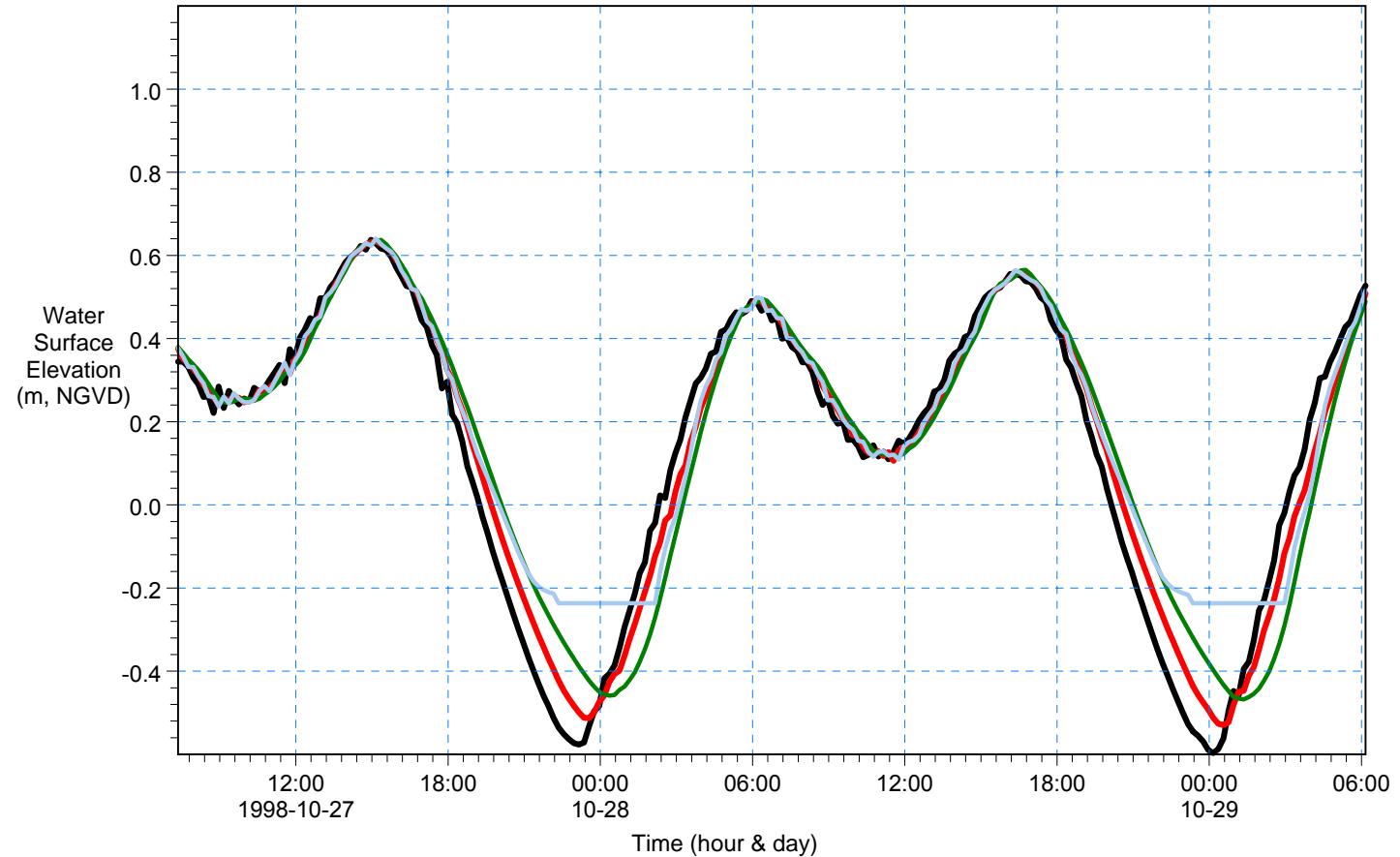
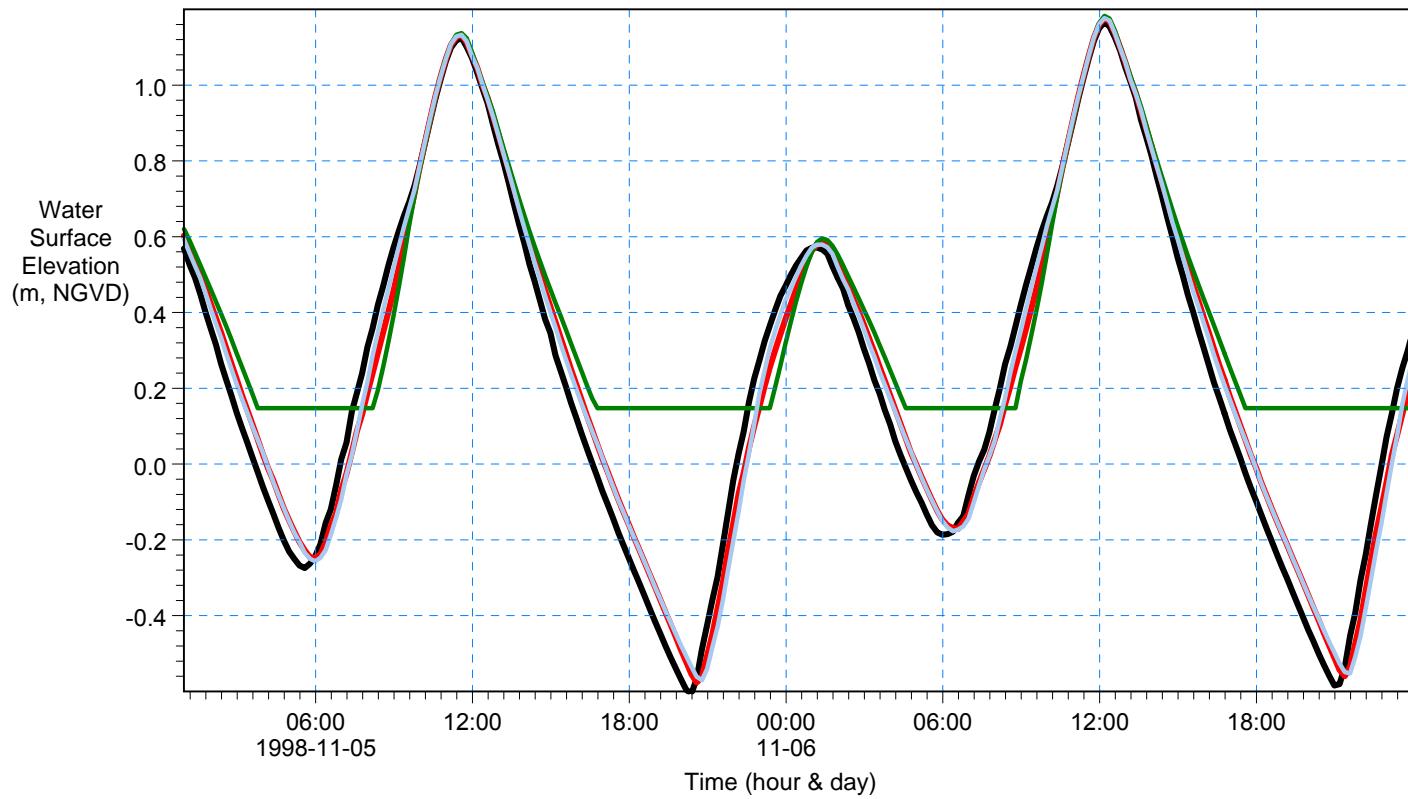


Figure 6.2e: Predicted Tidal Amplitudes in Bolinas Lagoon: Central & South Scenario

South Arm: CE & SO WSEs [m] —————
 East Channel: CE & SO WSEs [m] —————
 North Lagoon: CE & SO WSEs [m] —————
 South Channel: CE & SO WSEs [m] —————

6.2e.1: Spring Tidal Cycle



South Arm Channel: Ce. and So. neap WSEs [m] —————
 East Channel: Ce. and So. neap WSEs [m] —————
 North Lagoon: Ce. and So. neap WSEs [m] —————
 South Channel: Ce. and So. neap WSEs [m] —————

6.2e.2: Neap Tidal Cycle

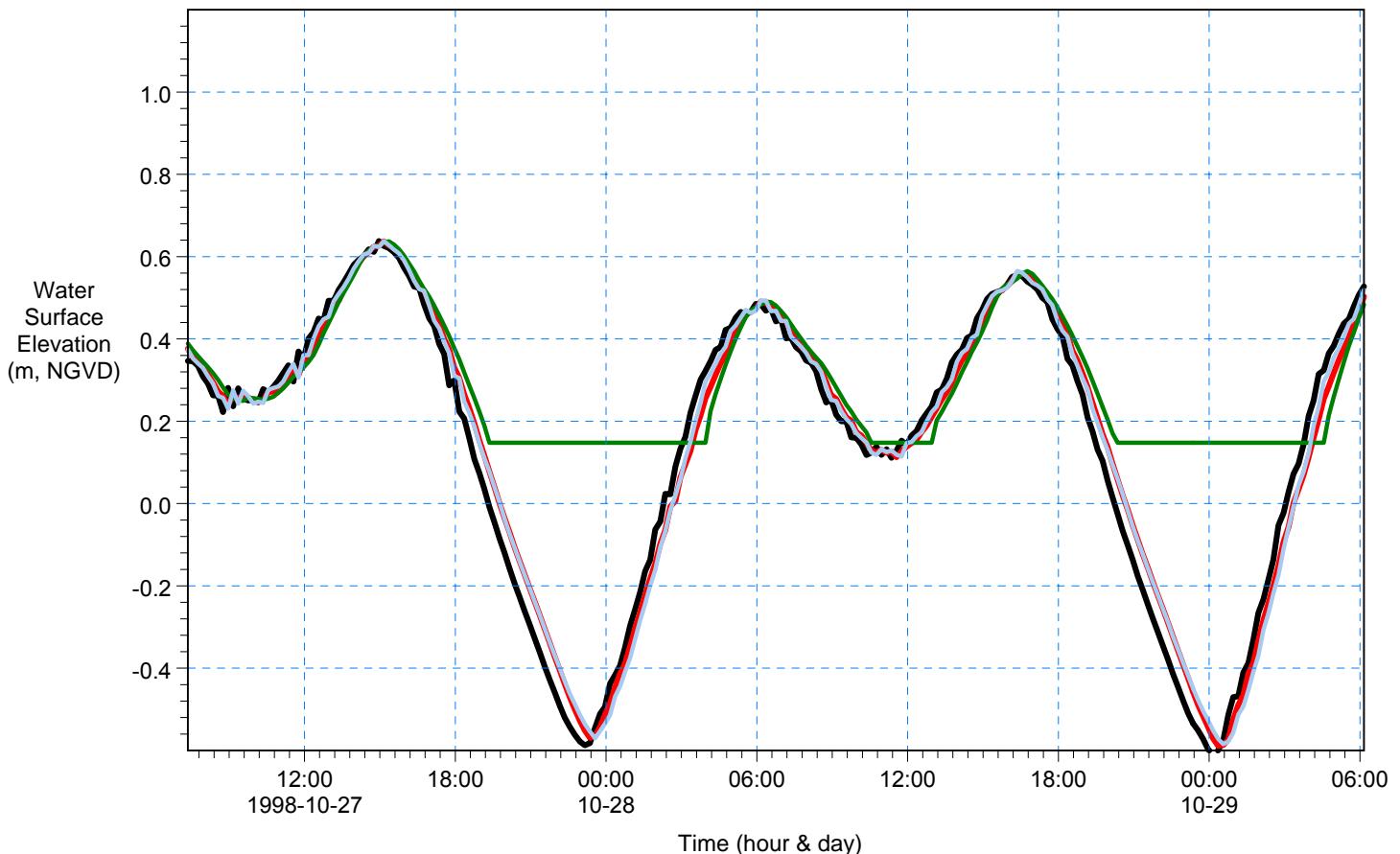


Figure 6.2f Predicted Tidal Amplitudes in Bolinas Lagoon: South Arm Channel

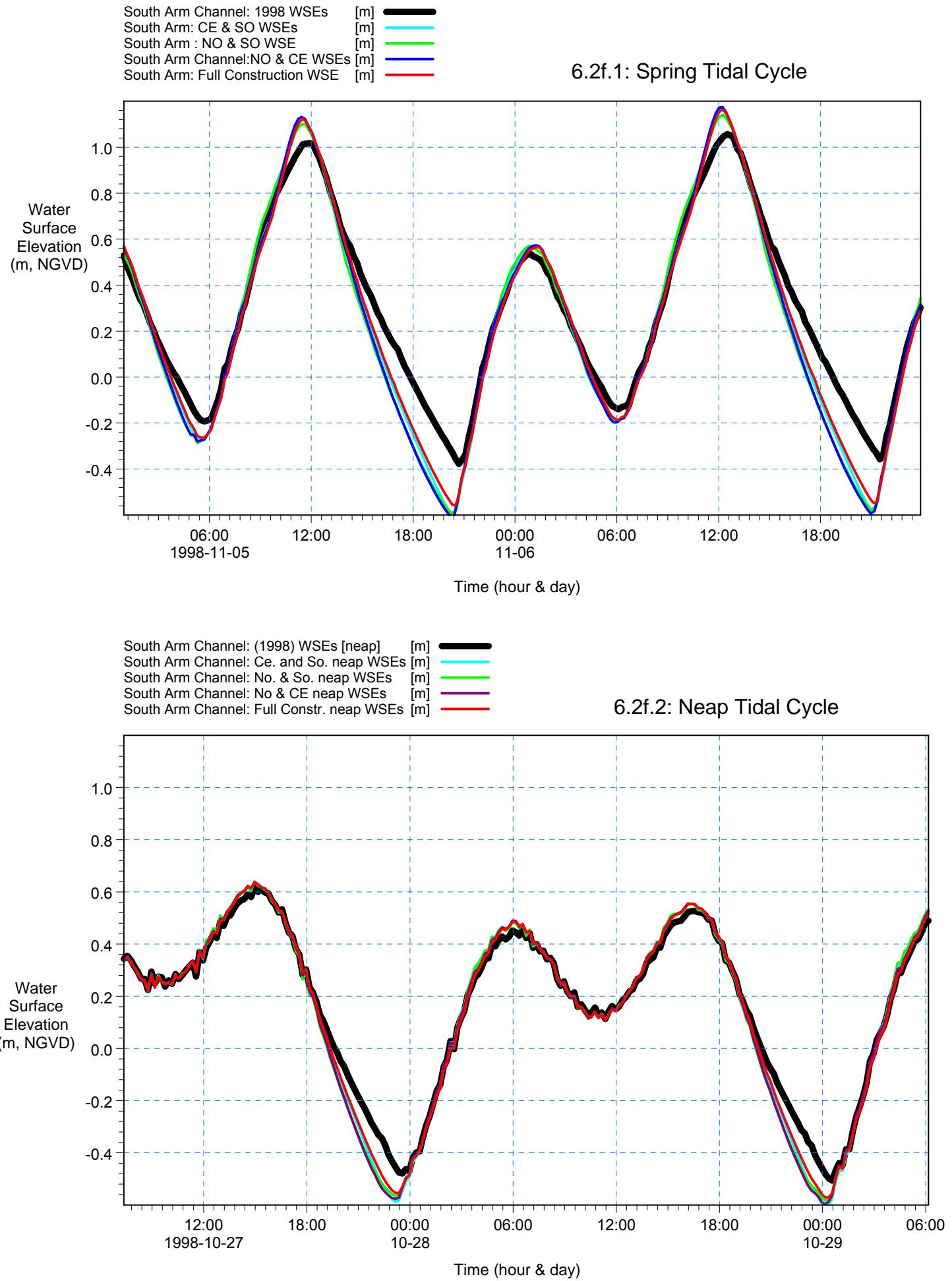
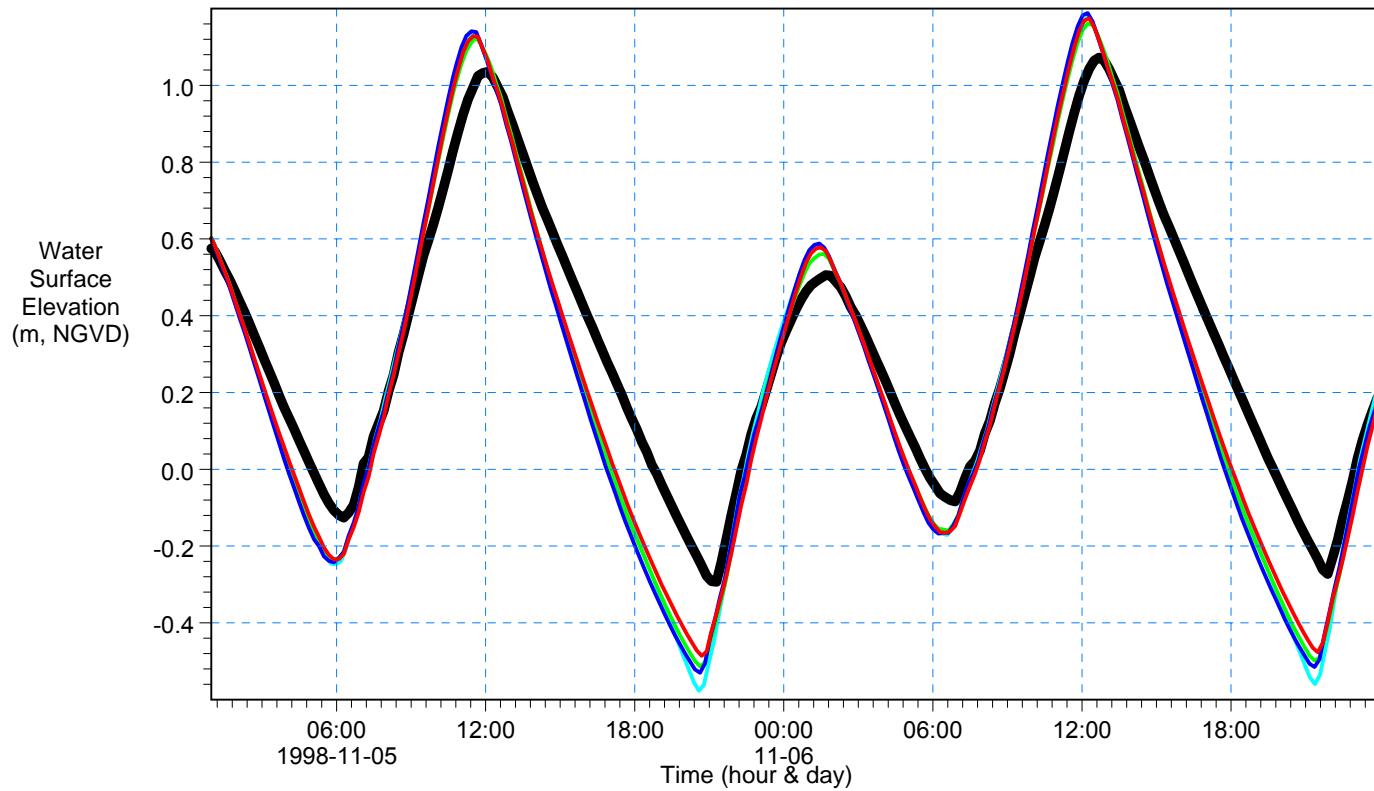


Figure 6.2g: Predicted Tidal Amplitudes in Bolinas Lagoon: East Channel

East Channel: 1998 WSEs [m] ——————
 East Channel: CE & SO WSEs [m] ——————
 East Channel: NO & SO WSE [m] ——————
 East Channel: NO & CE WSEs [m] ——————
 East Channel: Full Construction WSE [m] ——————

6.2g.1: Spring Tidal Cycle



East Channel: (1998) WSEs [neap] [m] ——————
 East Channel: Ce. and So. neap WSEs [m] ——————
 East Channel: No. & So. neap WSEs [m] ——————
 East Channel: No & CE neap WSEs [m] ——————
 East Channel: Full Constr. neap WSEs [m] ——————

6.2g.2: Neap Tidal Cycle

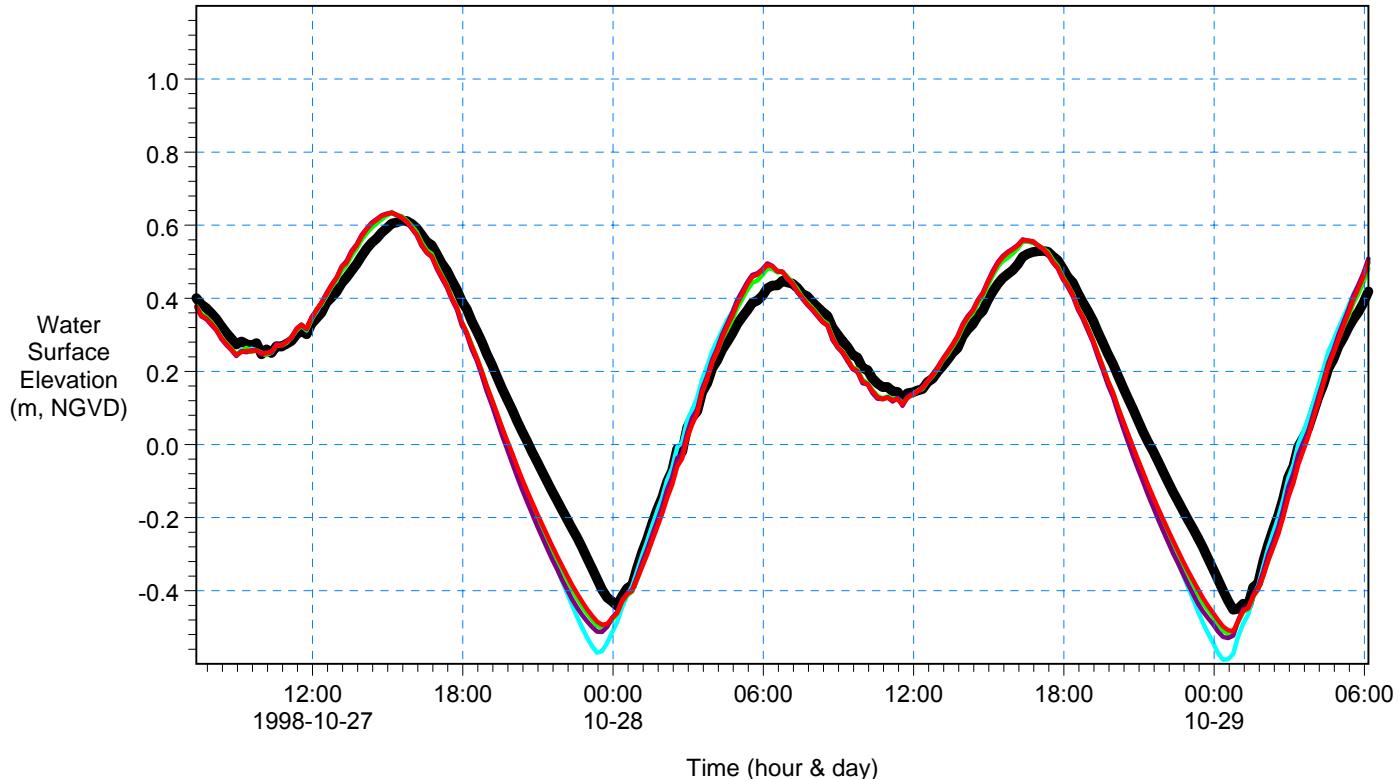


Figure 6.2h: Predicted Tidal Amplitudes in Bolinas Lagoon: North Lagoon

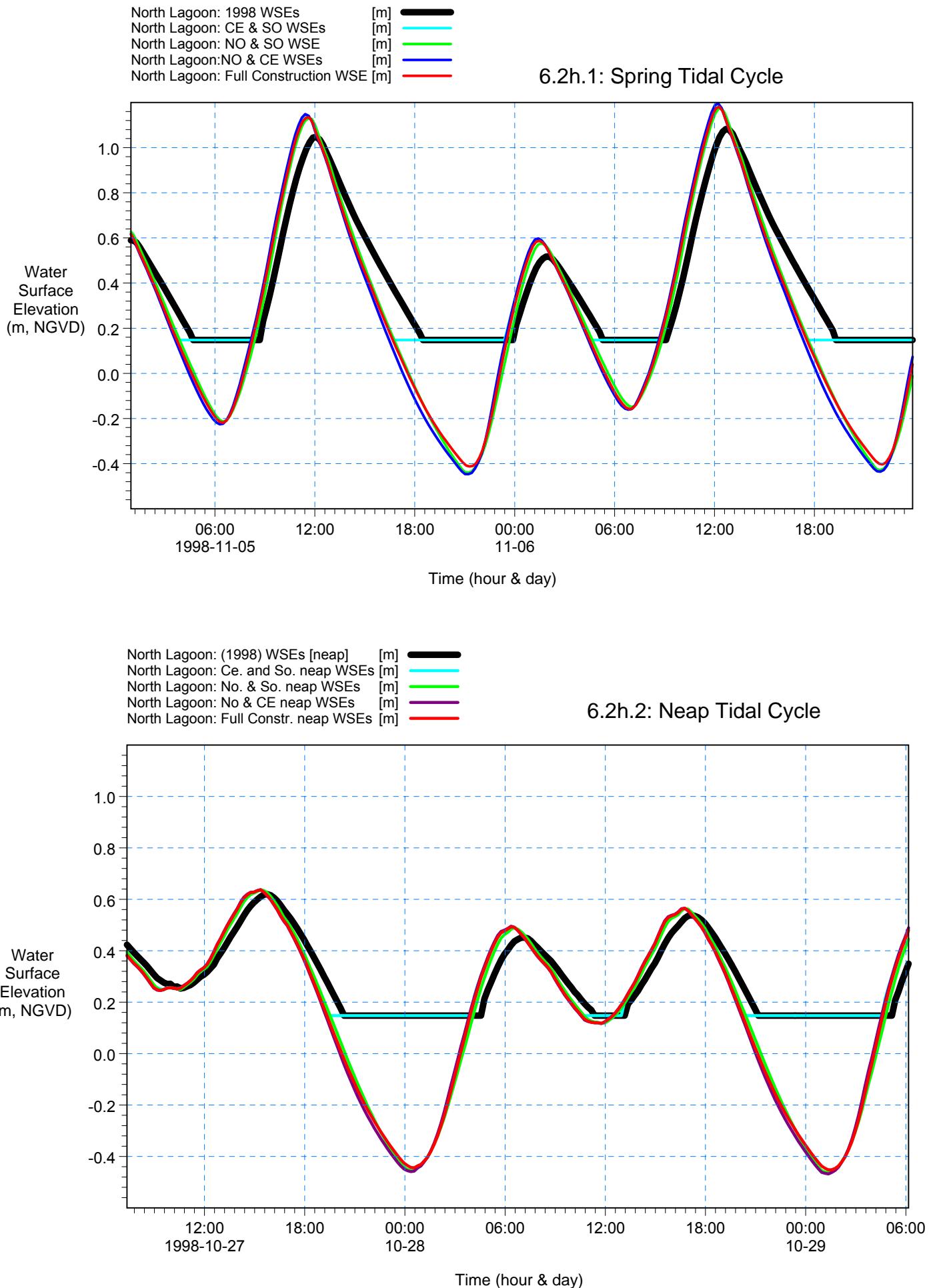


Figure 6.2i: Predicted Tidal Amplitudes in Bolinas Lagoon: South Lagoon Channel

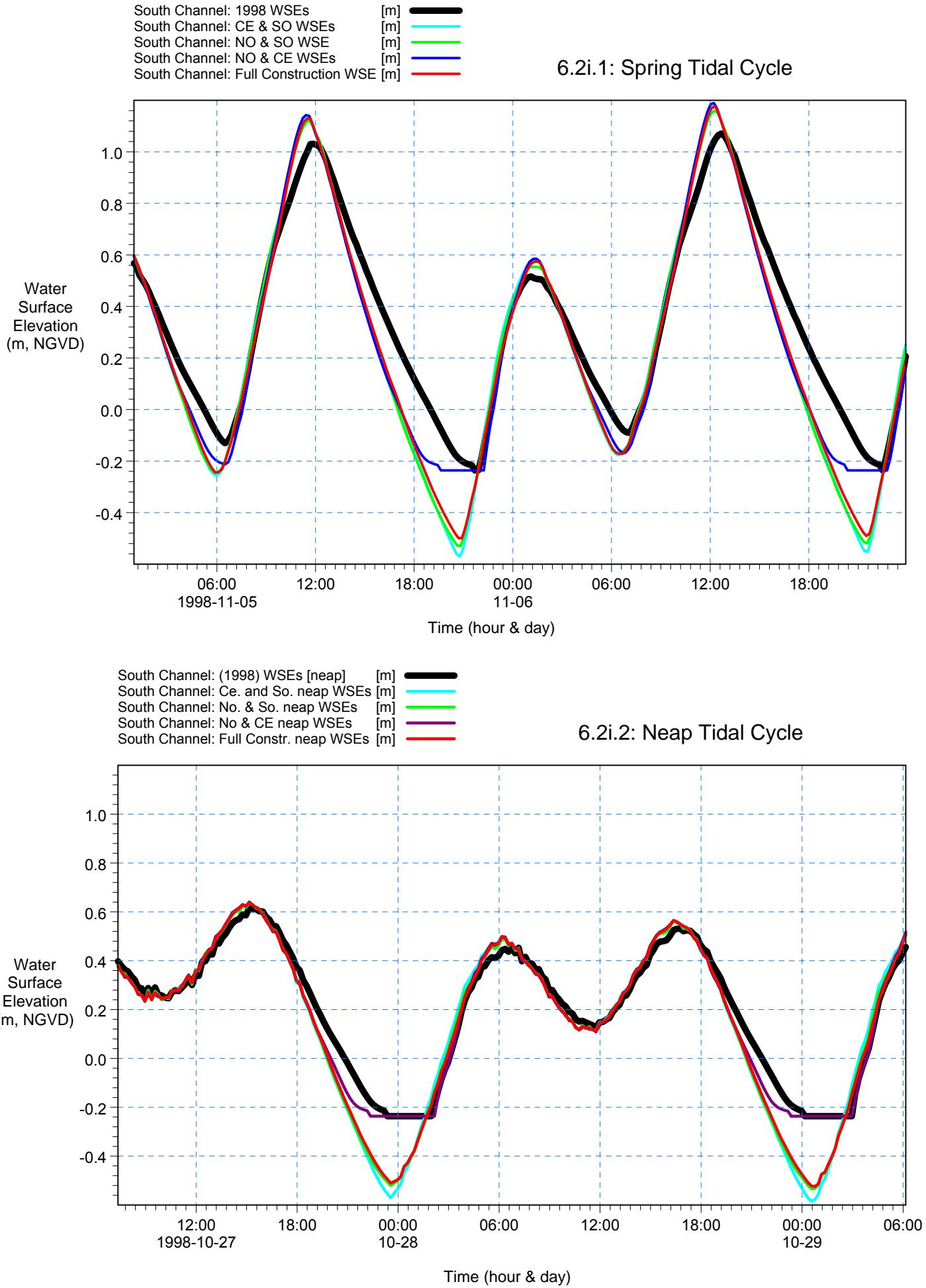


Figure 6.2j: Predicted Tidal Amplitudes in Bolinas Lagoon: Seadrift Lagoon

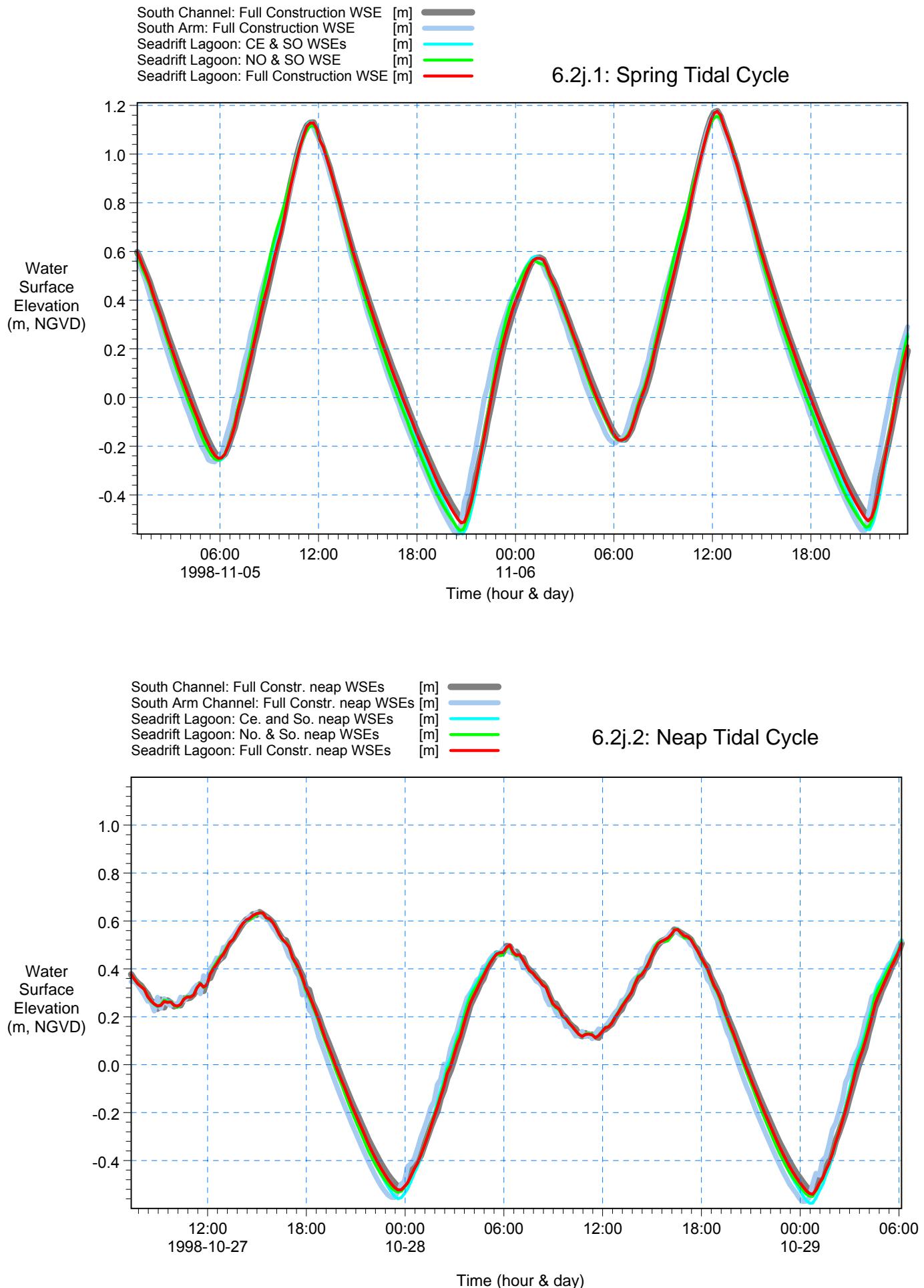


Figure 6.3a: Predicted Spring and Neap Velocities: Bolinas Inlet

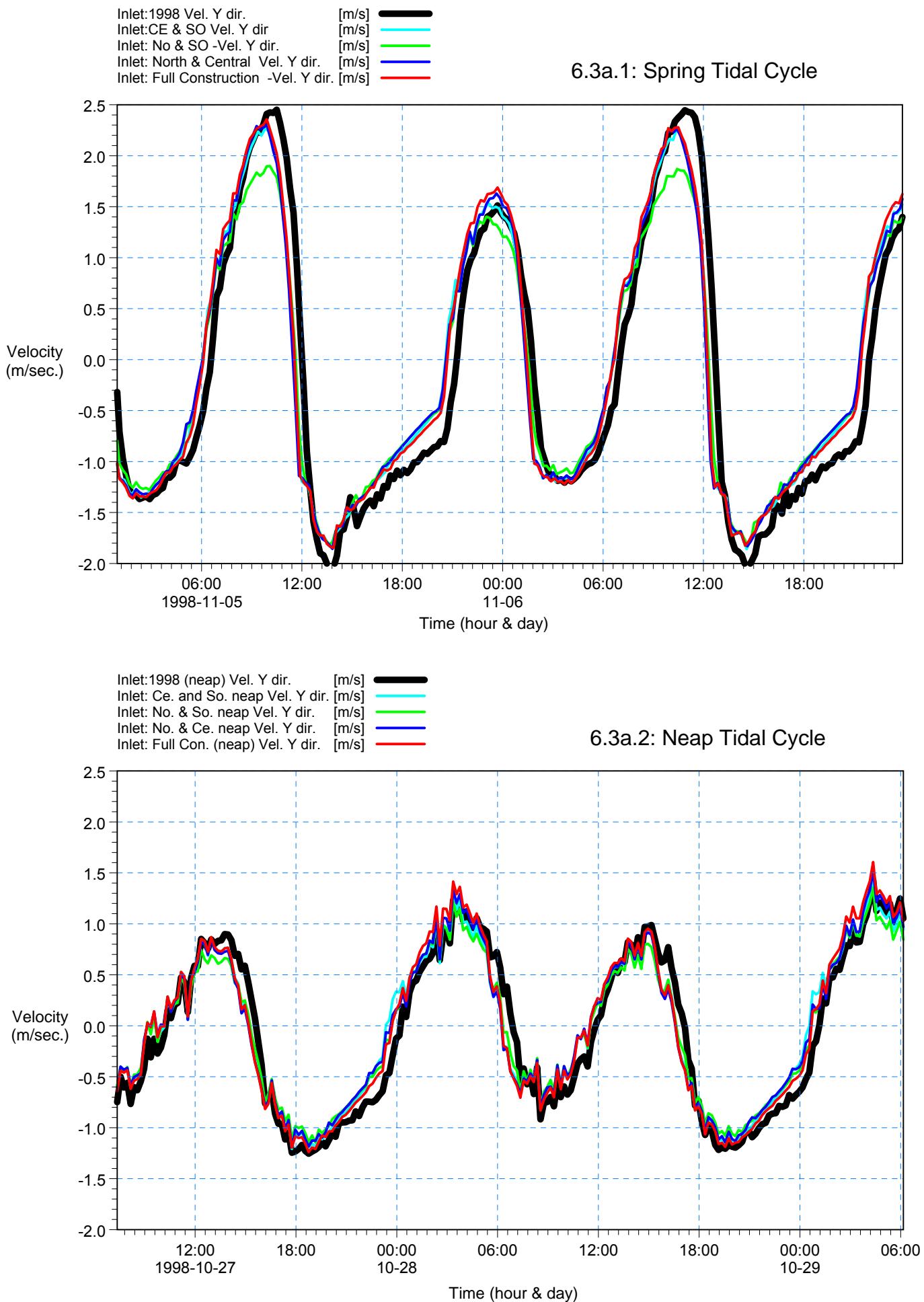
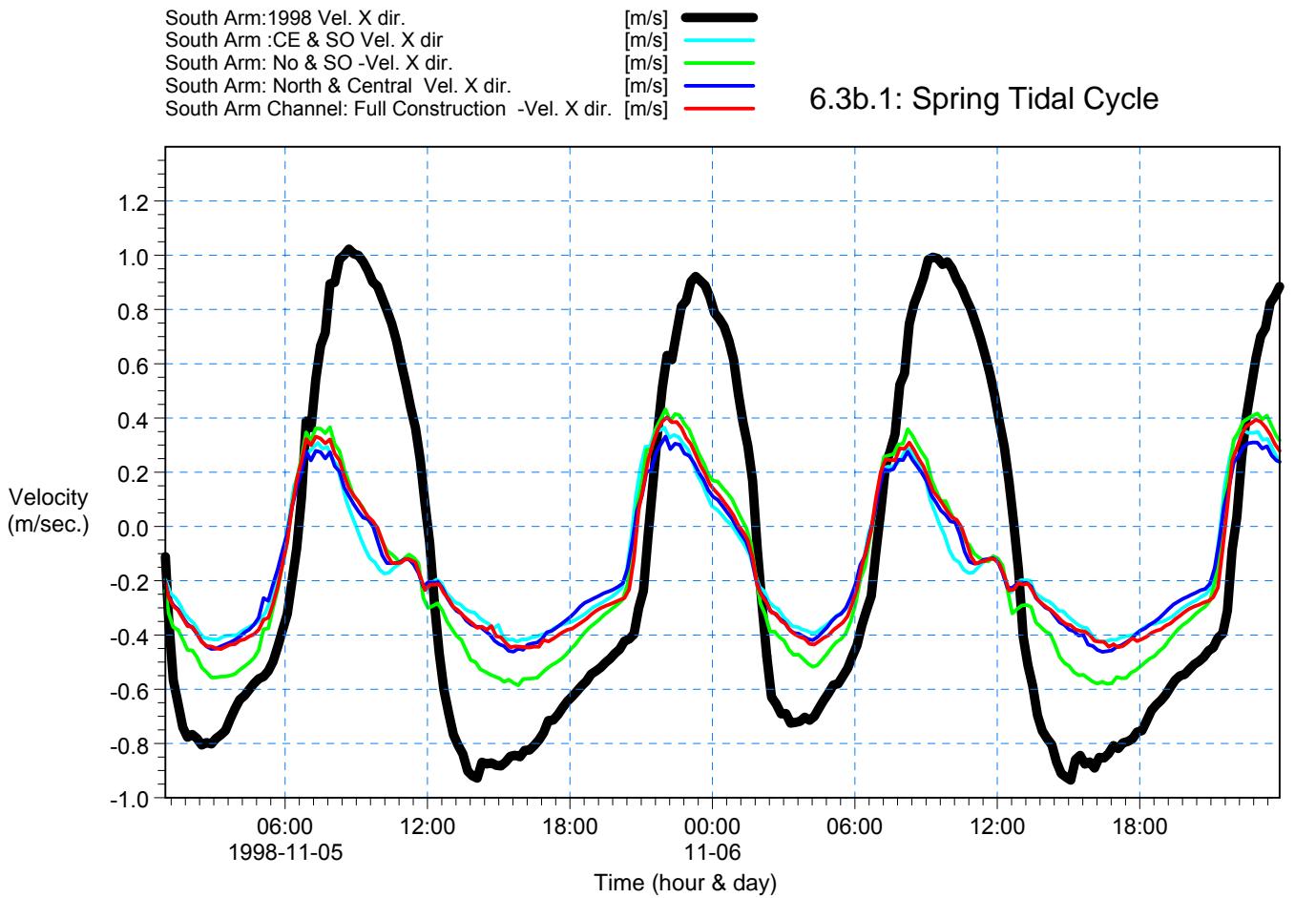


Figure 6.3b: Predicted Spring and Neap Velocities: South Arm Channel



South Arm:1998 (neap) Vel. X dir. [m/s] —
 South Arm Channel: Ce. and So. neap Vel. X dir. [m/s] —
 South Arm Channel: No. & So. neap Vel. X dir. [m/s] —
 South Arm Channel: No. & Ce. neap Vel. X dir. [m/s] —
 South Arm Channel: Full Con. (neap) Vel. X dir. [m/s] —

6.3b.2: Neap Tidal Cycle

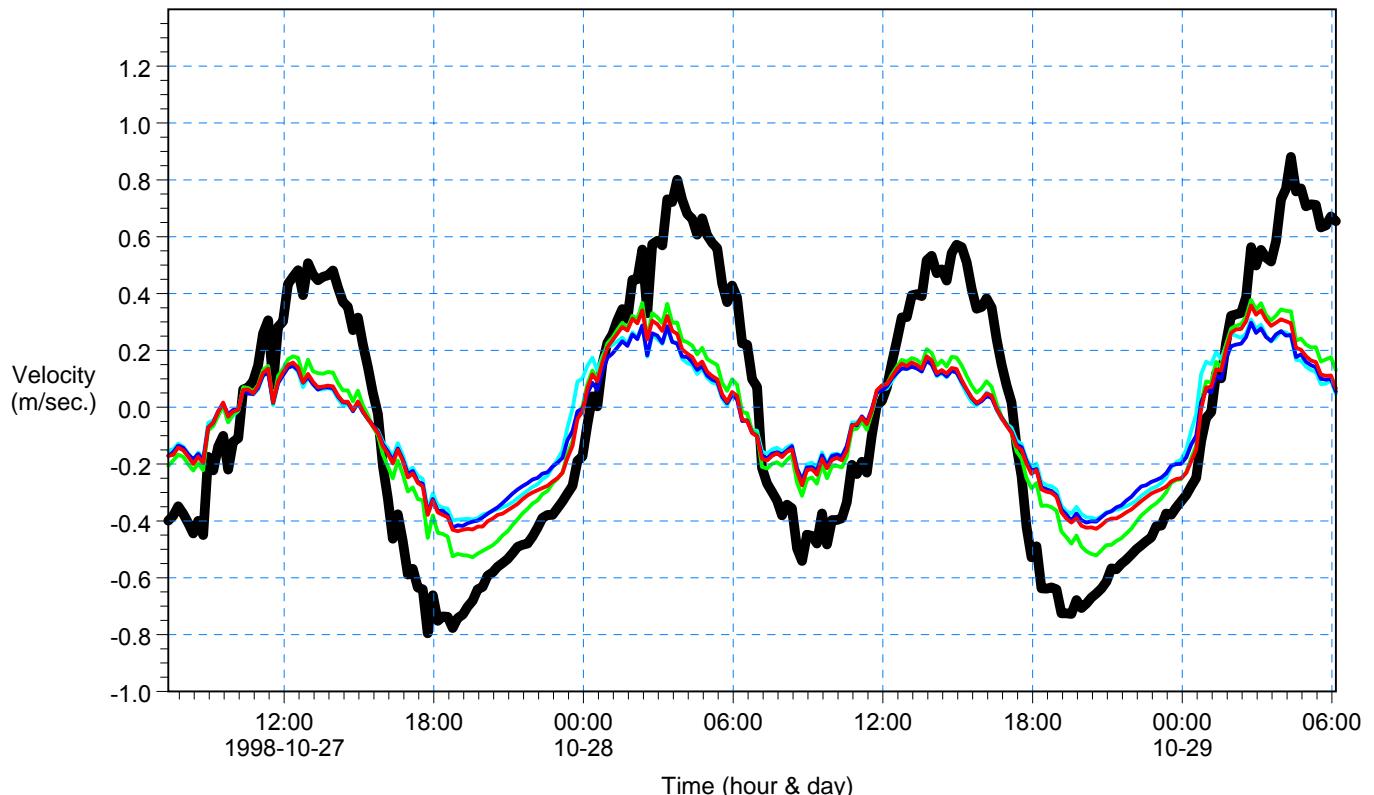
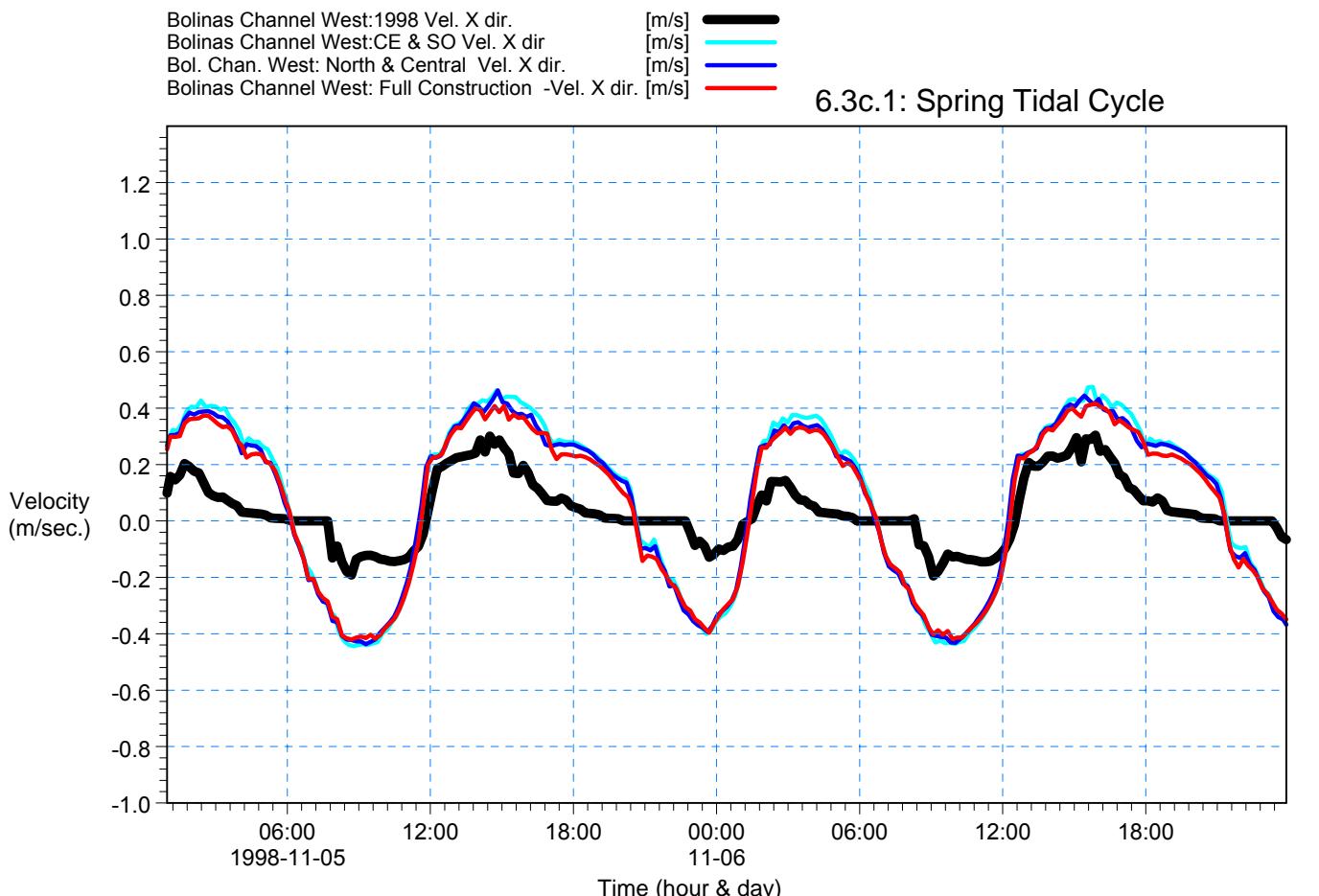


Figure 6.3c: Predicted Spring and Neap Velocities: Bolinas Channel (west)



Bolinas Channel [west]:1998 (neap) Vel. X dir. [m/s] —
 Bolinas Channel [west]: Ce. and So. neap Vel. X dir. [m/s] —
 Bolinas Channel [west]: No. & Ce. neap Vel. X dir. [m/s] —
 Bolinas Channel [west]: Full Con. (neap) Vel. X dir. [m/s] —

6.3c.2: Neap Tidal Cycle

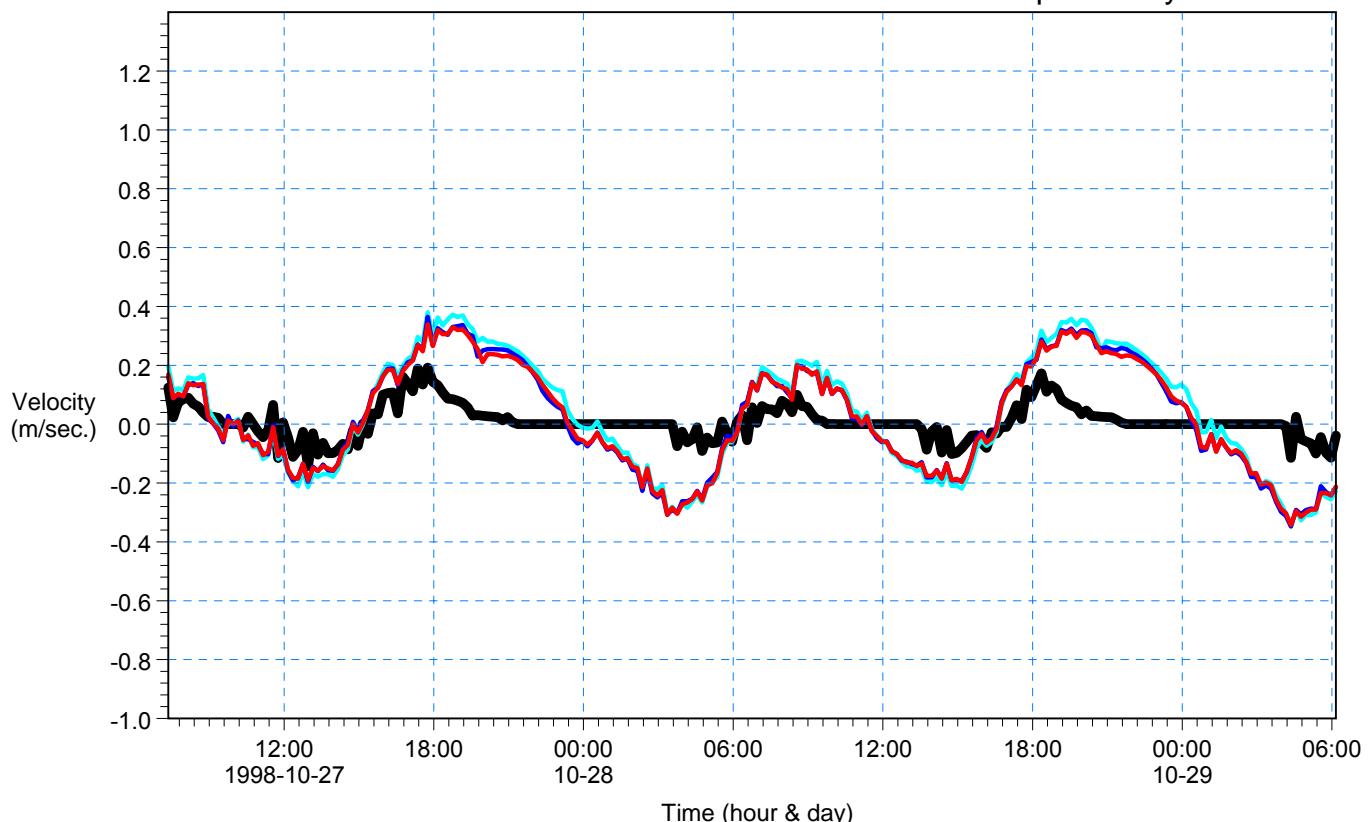


Figure 6.3d: Predicted Spring and Neap Velocities: Bolinas Channel (east)

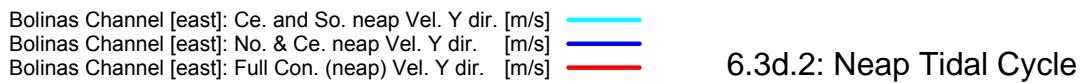
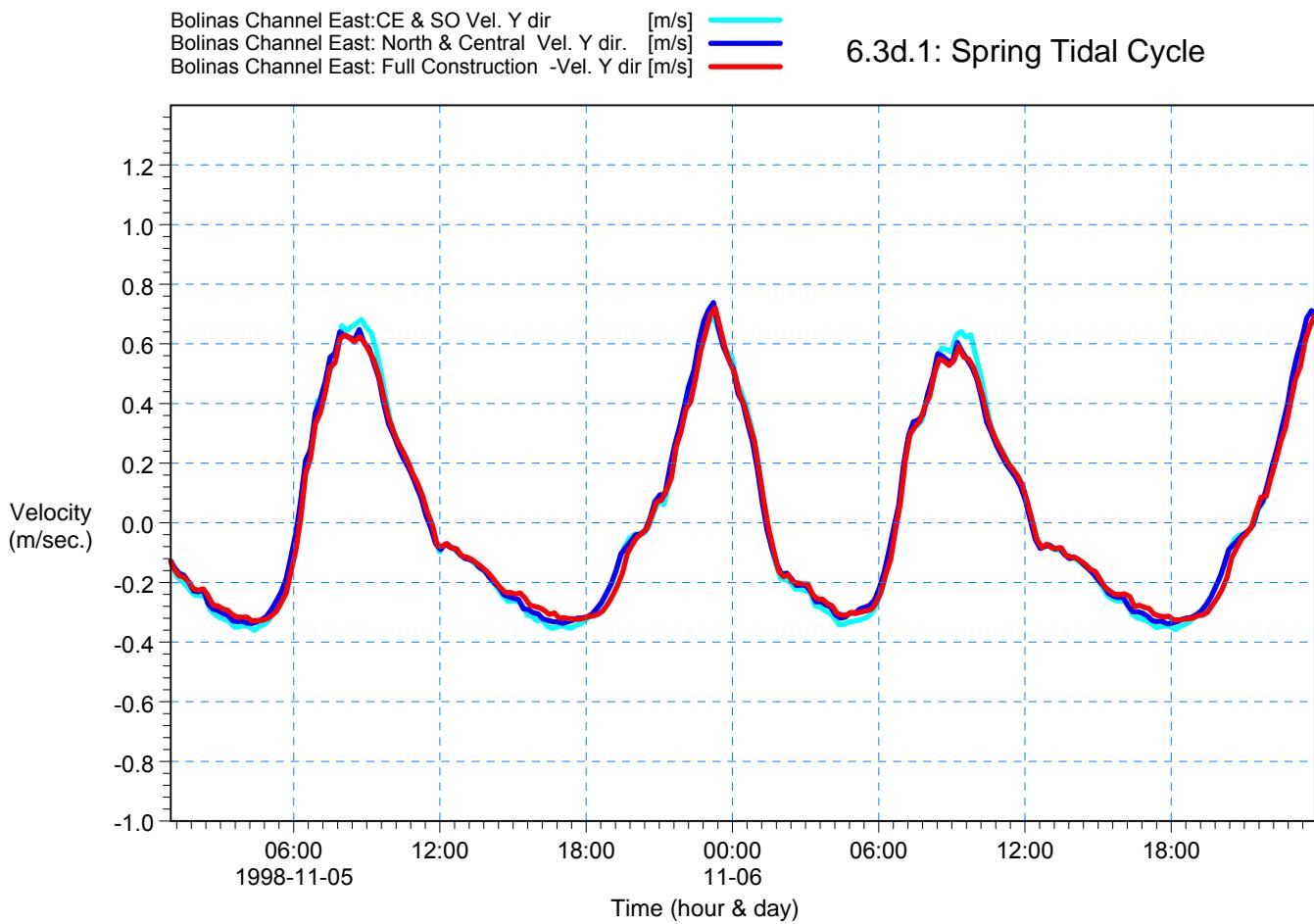
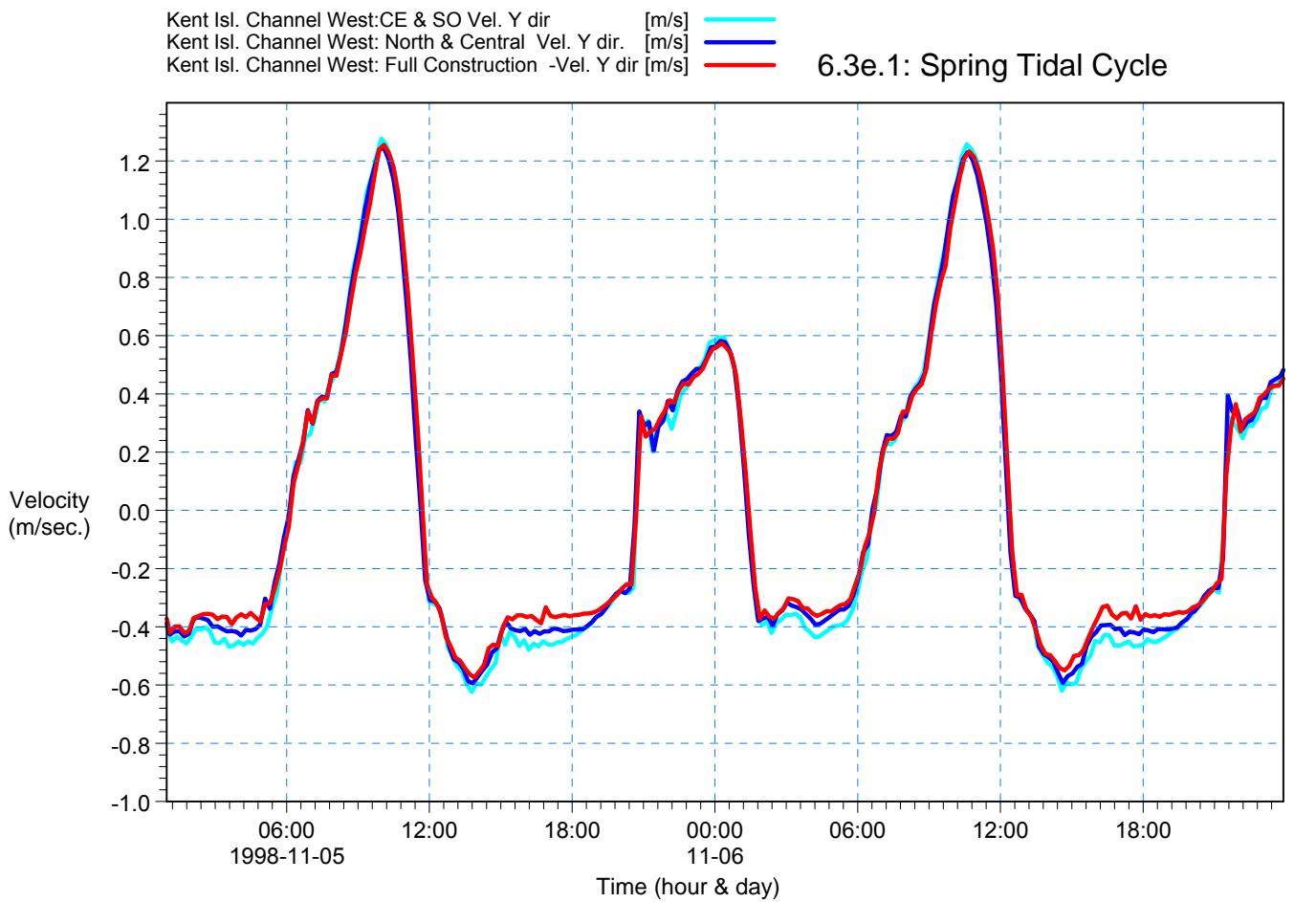


Figure 6.3e: Predicted Spring and Neap Velocities: Kent Island Channel (west)



Kent Isl. Channel [west]: Ce. and So. neap Vel. Y dir. [m/s] — cyan line
 Kent Isl. Channel [west]: No. & Ce. neap Vel. Y dir. [m/s] — blue line
 Kent Isl. Channel [west]: Full Con. (neap) Vel. Y dir. [m/s] — red line 6.3e.2: Neap Tidal Cycle

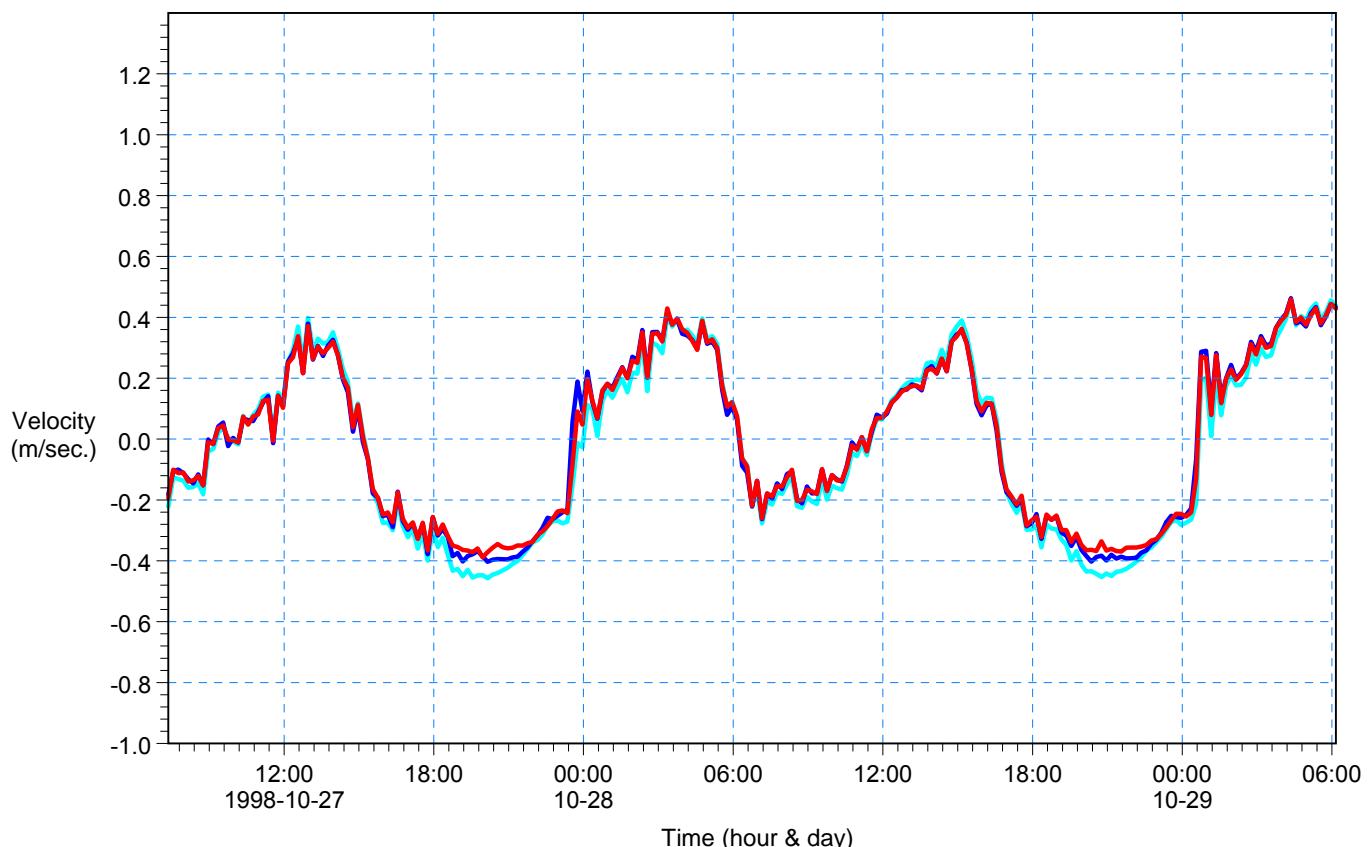


Figure 6.3f: Predicted Spring and Neap Velocities: Kent Island Channel (east)

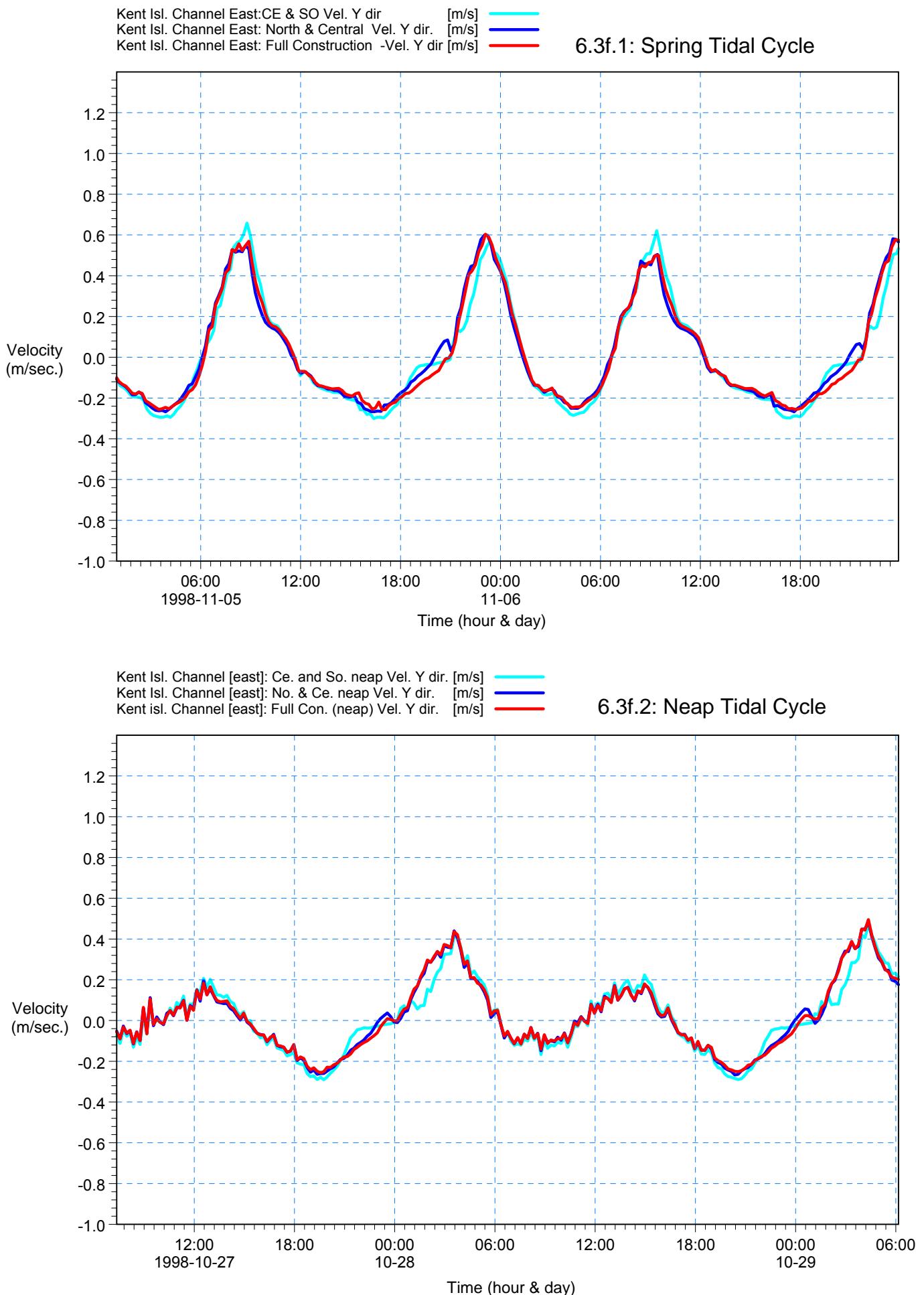
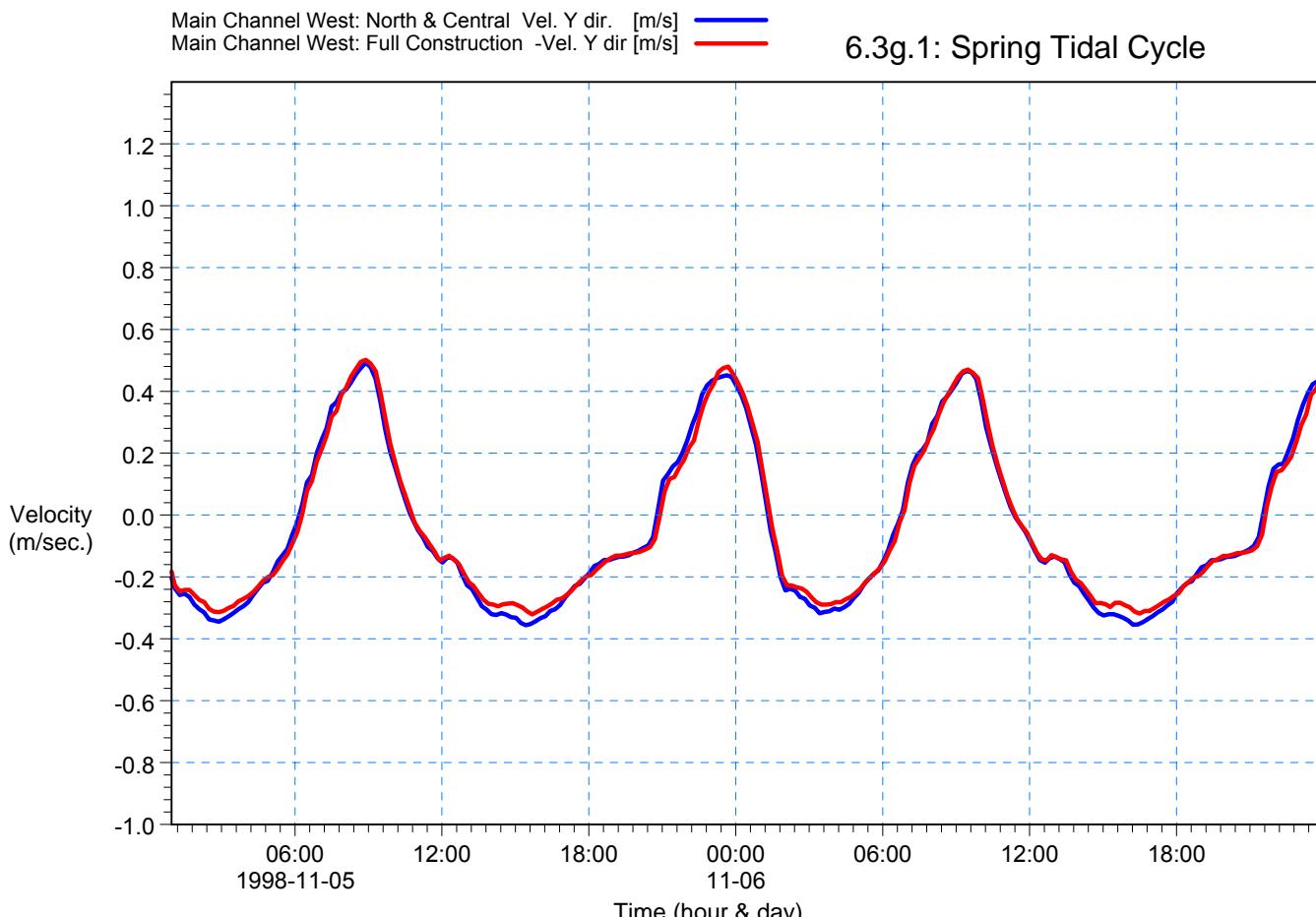


Figure 6.3g: Predicted Spring and Neap Velocities: Main Channel (west)



Main Channel [west]: No. & Ce. neap Vel. Y dir. [m/s] — Main Channel [west]: Full Con. (neap) Vel. Y dir. [m/s] — 6.3g.2: Neap Tidal Cycle

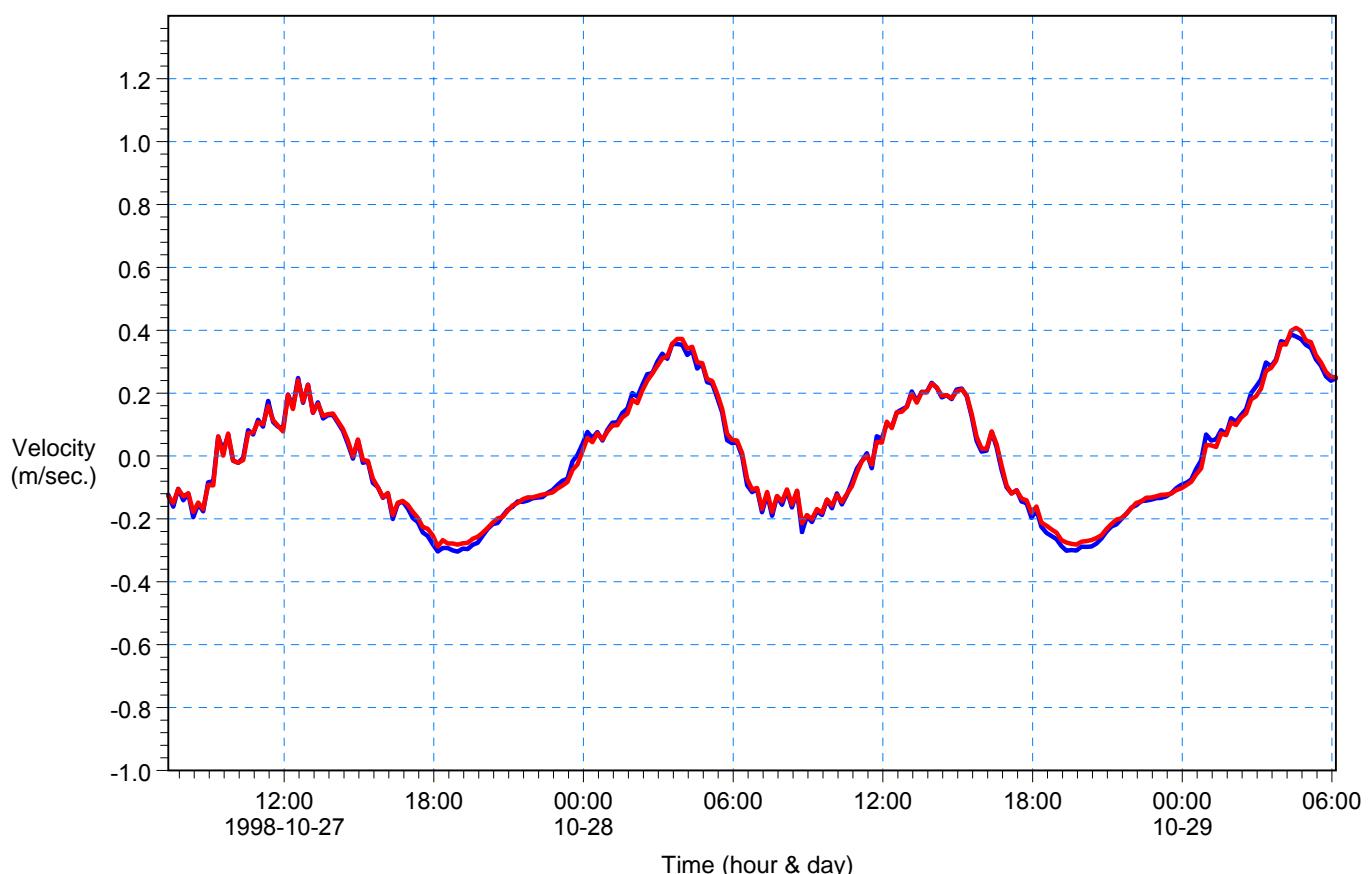


Figure 6.3h: Predicted Spring and Neap Velocities: Main Channel (east)

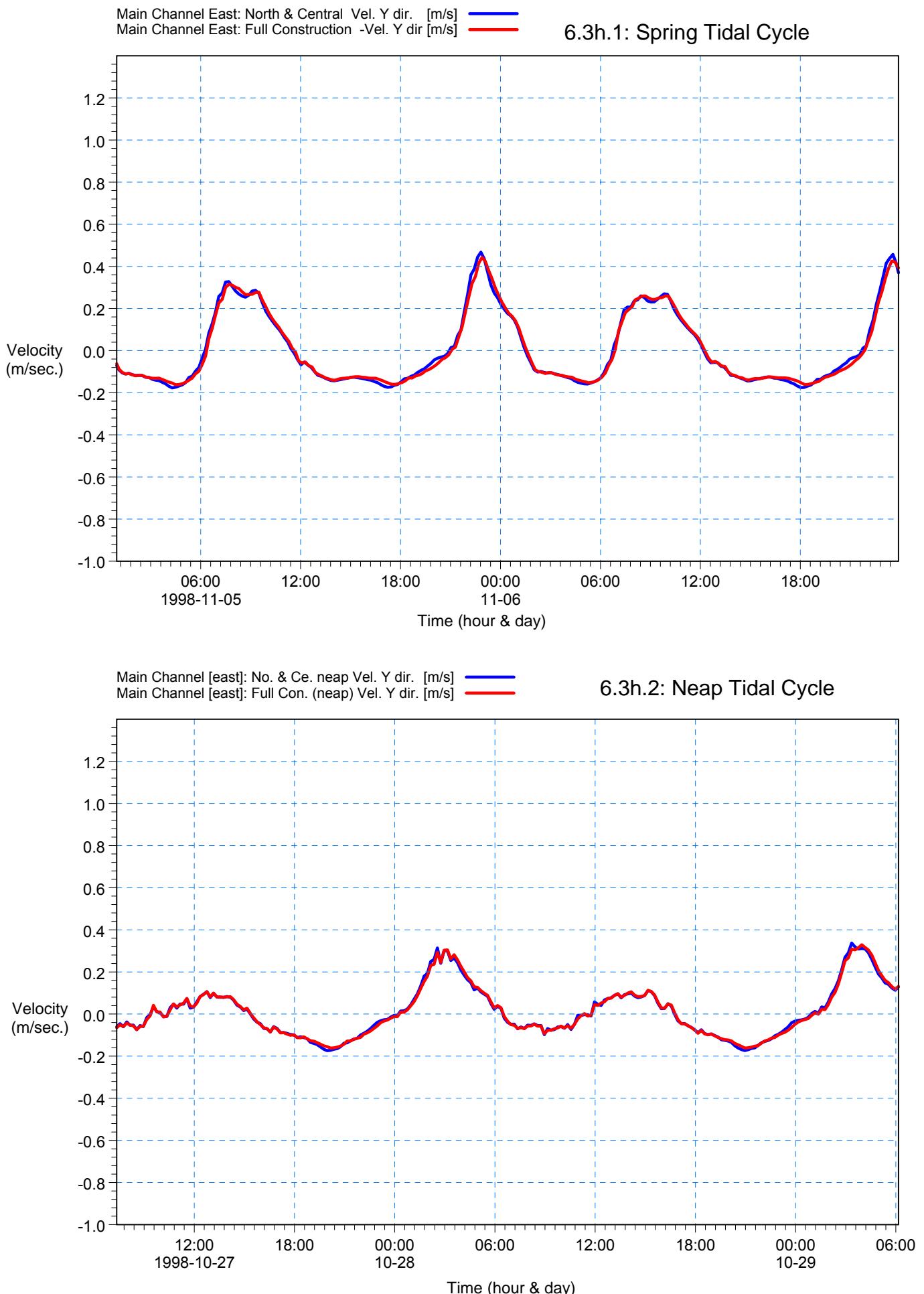


Figure 6.3i: Predicted Spring and Neap Velocities: East Channel

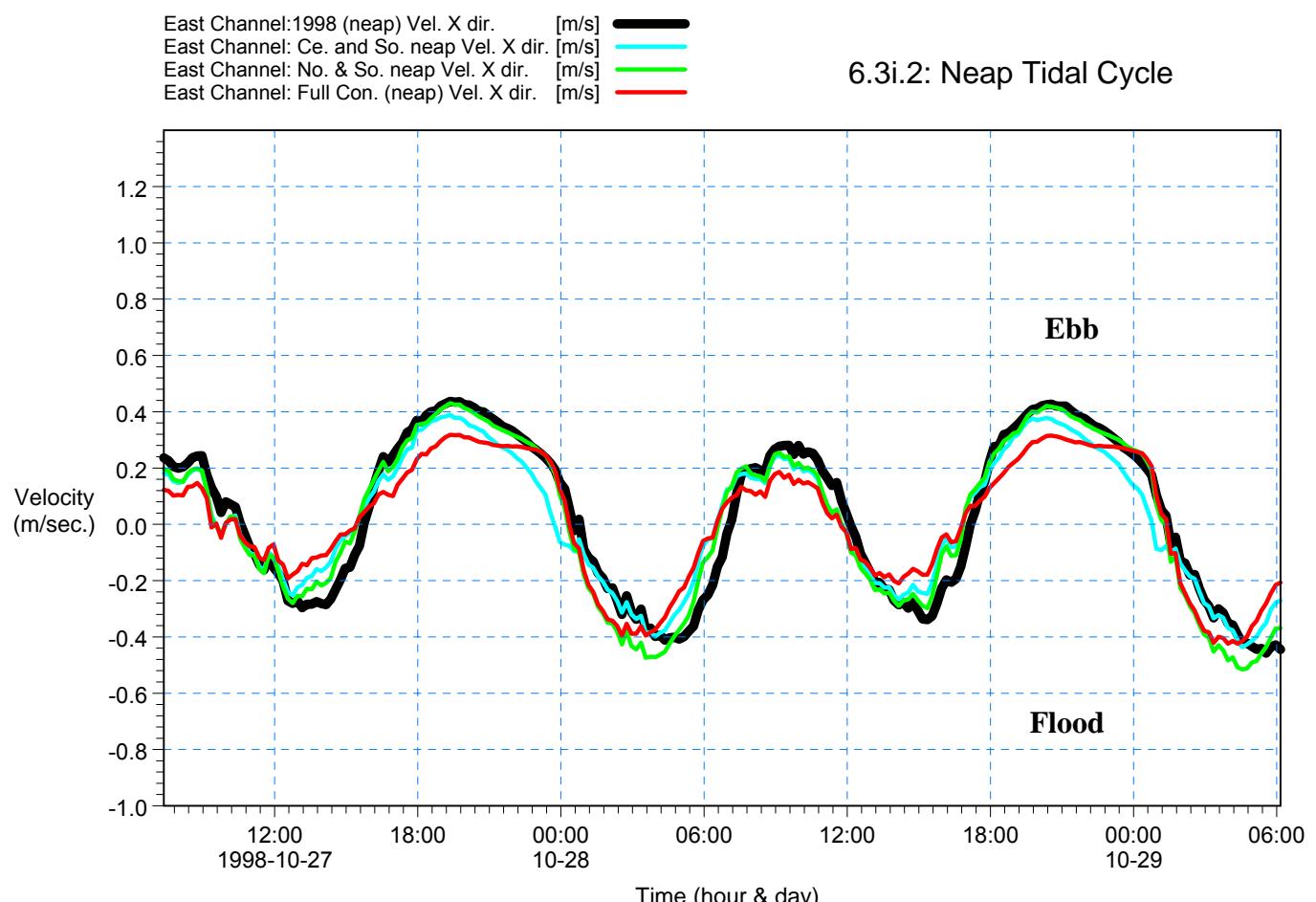
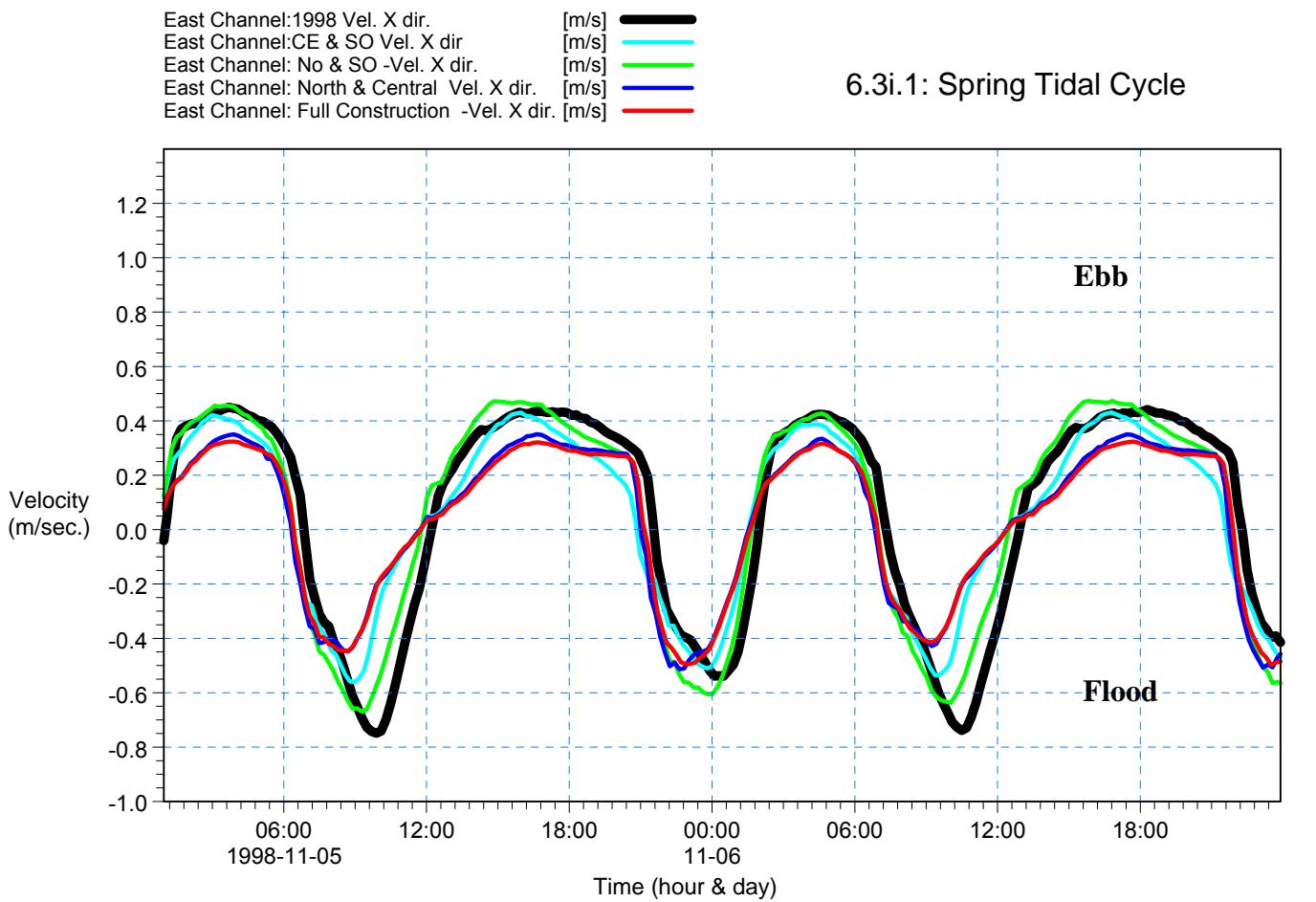
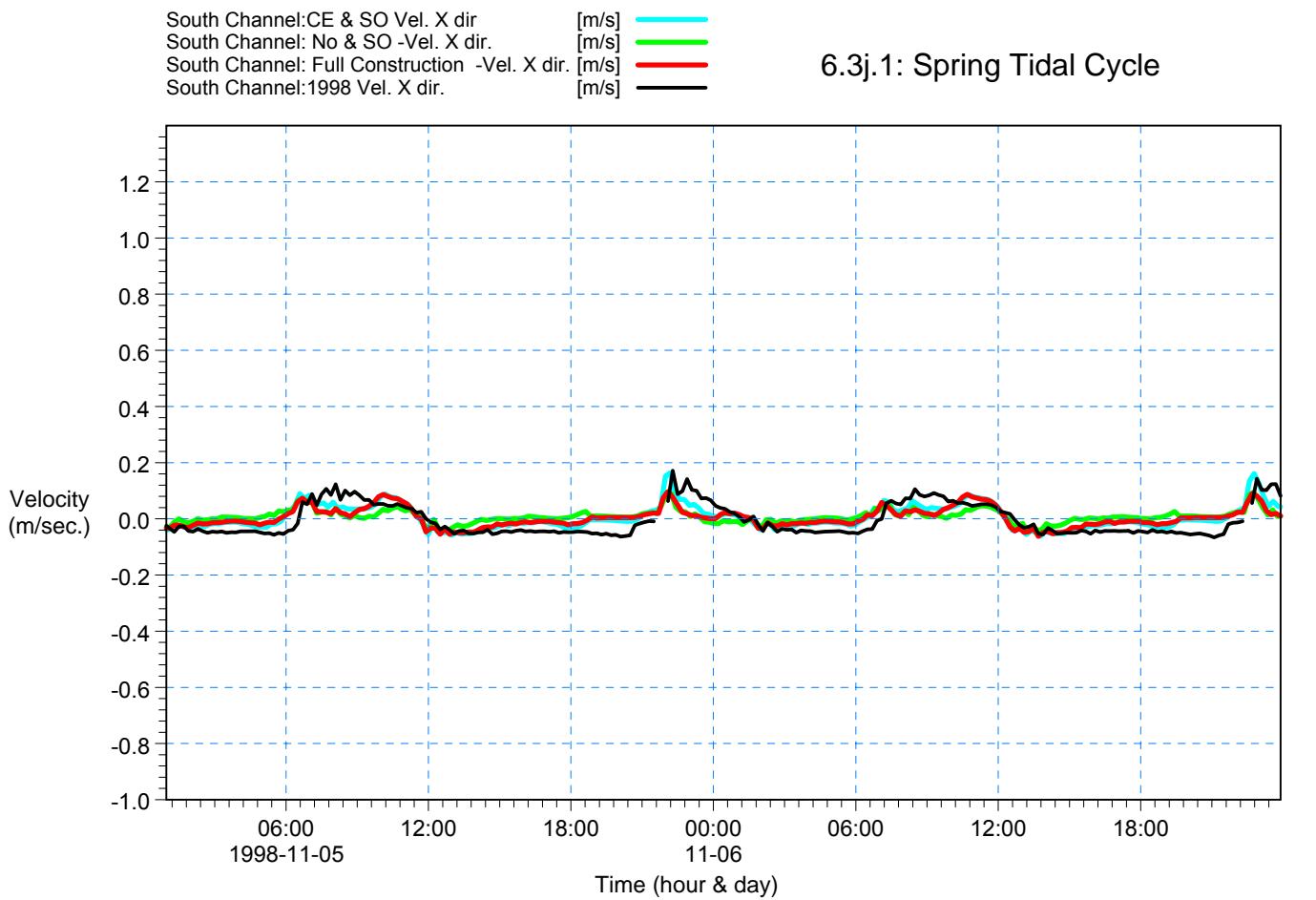


Figure 6.3j: Predicted Spring and Neap Velocities: South Lagoon Channel



South Channel: Ce. and So. neap Vel. X dir. [m/s] —
 South Channel: No. & So. neap Vel. X dir. [m/s] —
 South Channel: Full Con. (neap) Vel. X dir. [m/s] —

6.3j.2: Neap Tidal Cycle

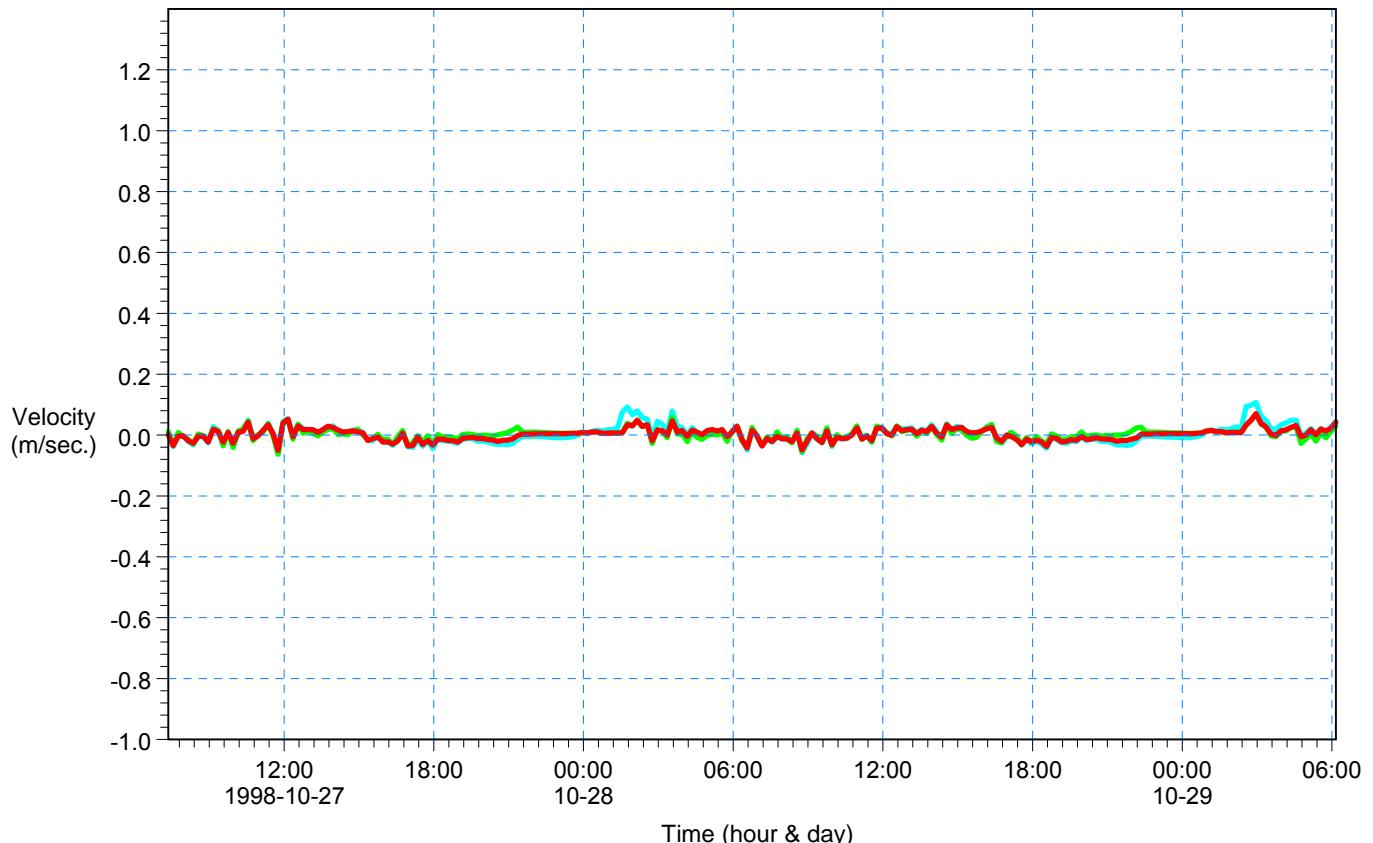
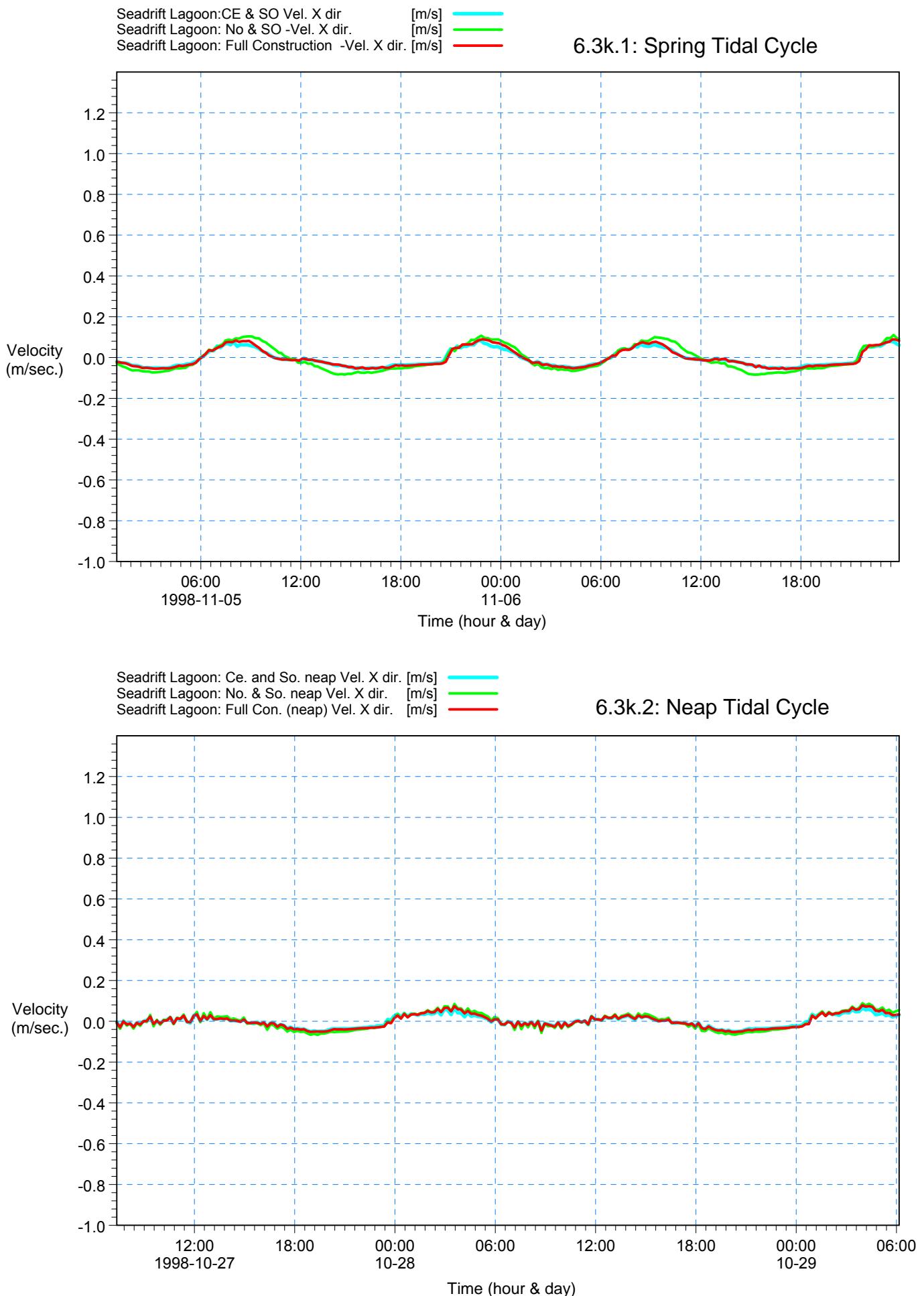


Figure 6.3k Predicted Spring and Neap Velocities: Seadrift Lagoon



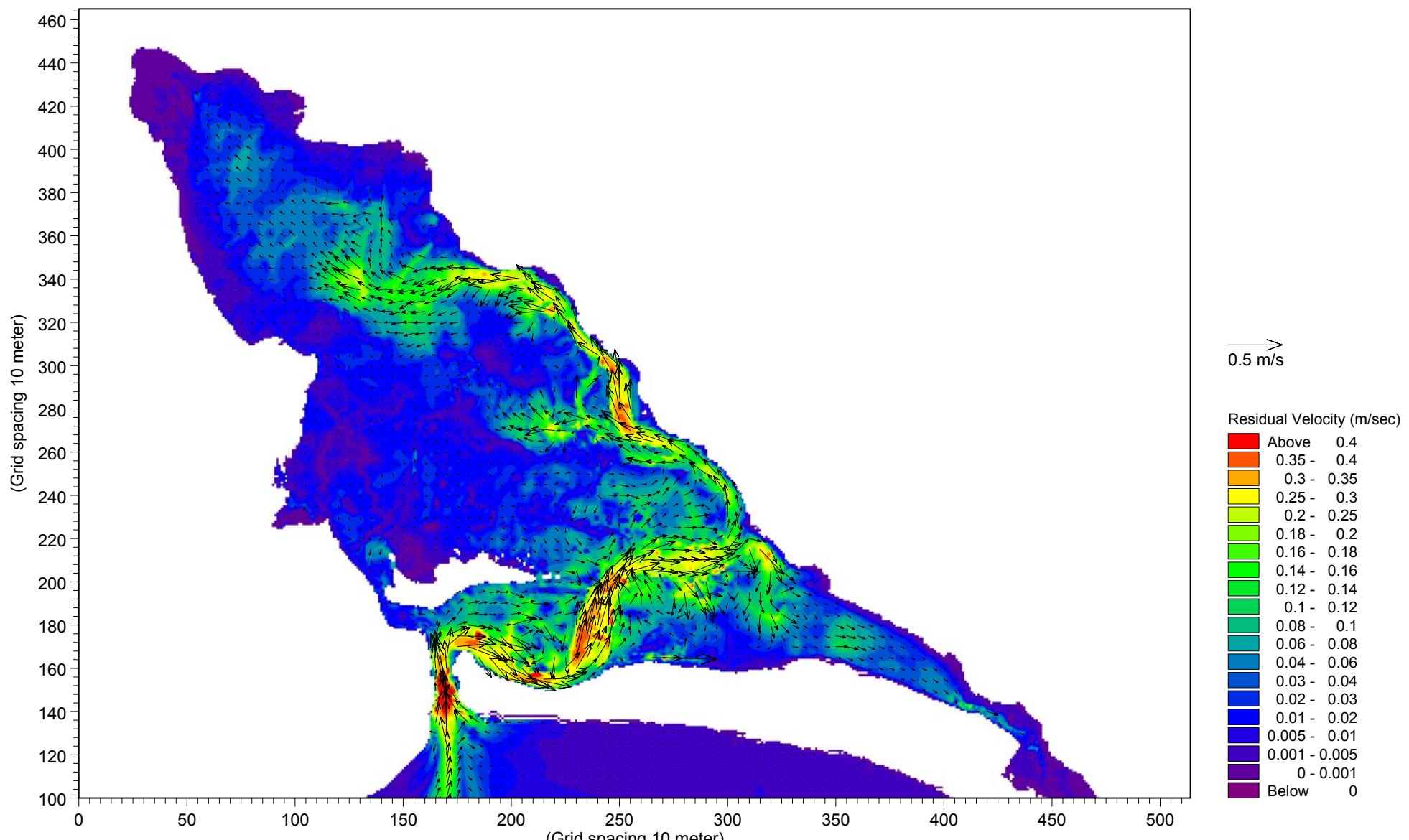


Figure 6.4a: Residual Velocities: Existing Conditions (1988) Scenario

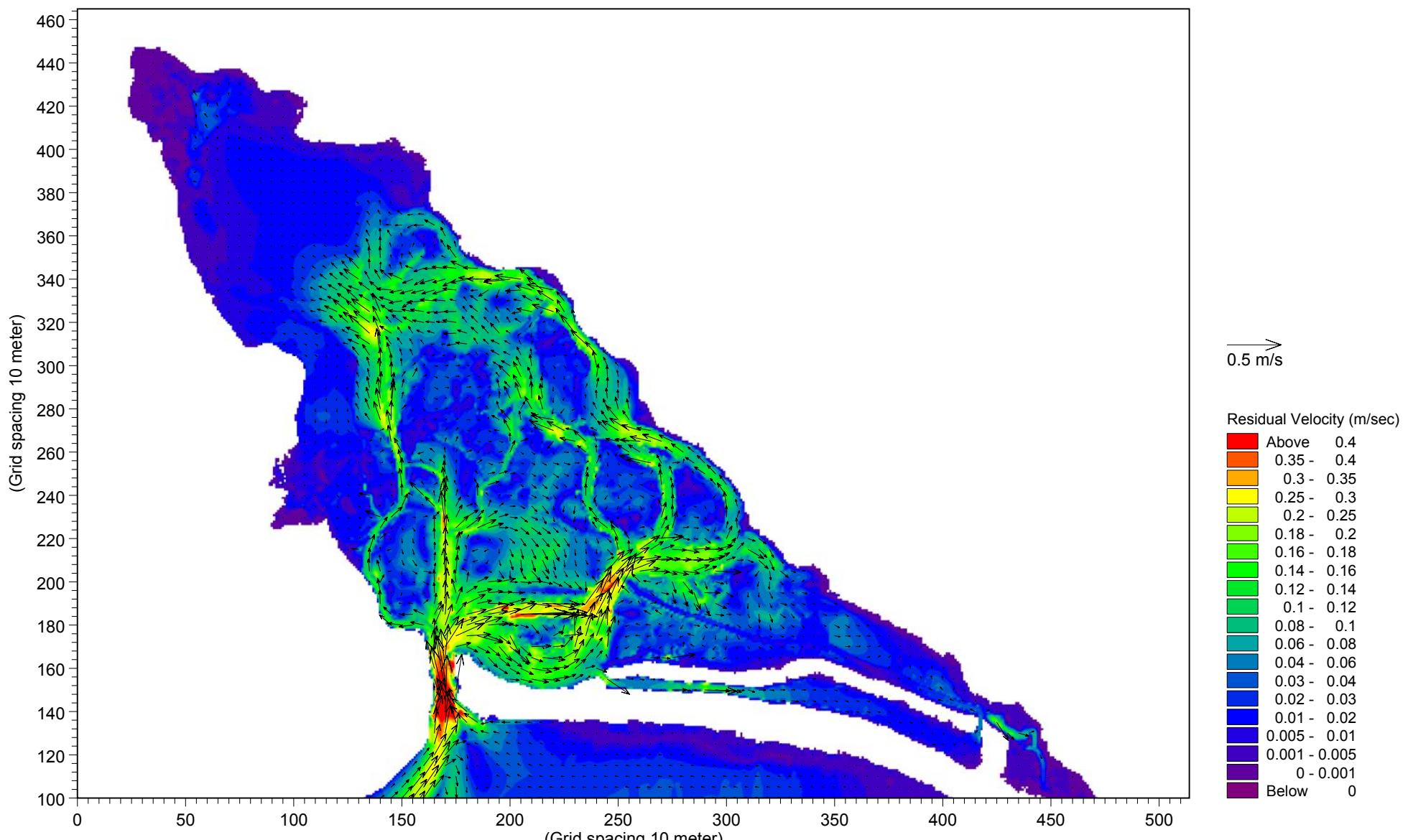


Figure 6.4b: Residual Velocities: Full Construction Scenario

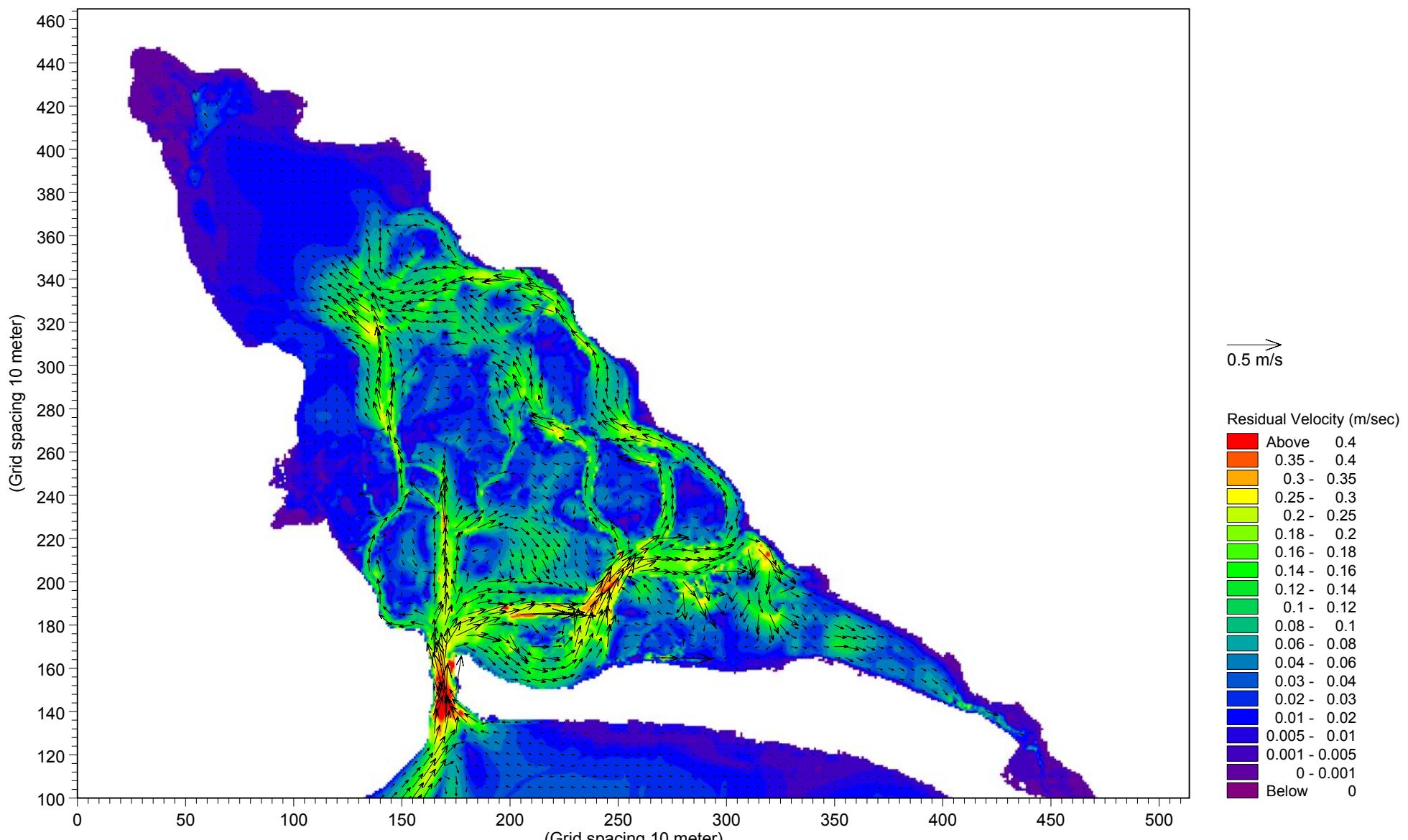


Figure 6.4c: Residual Velocities: North & Central Scenario

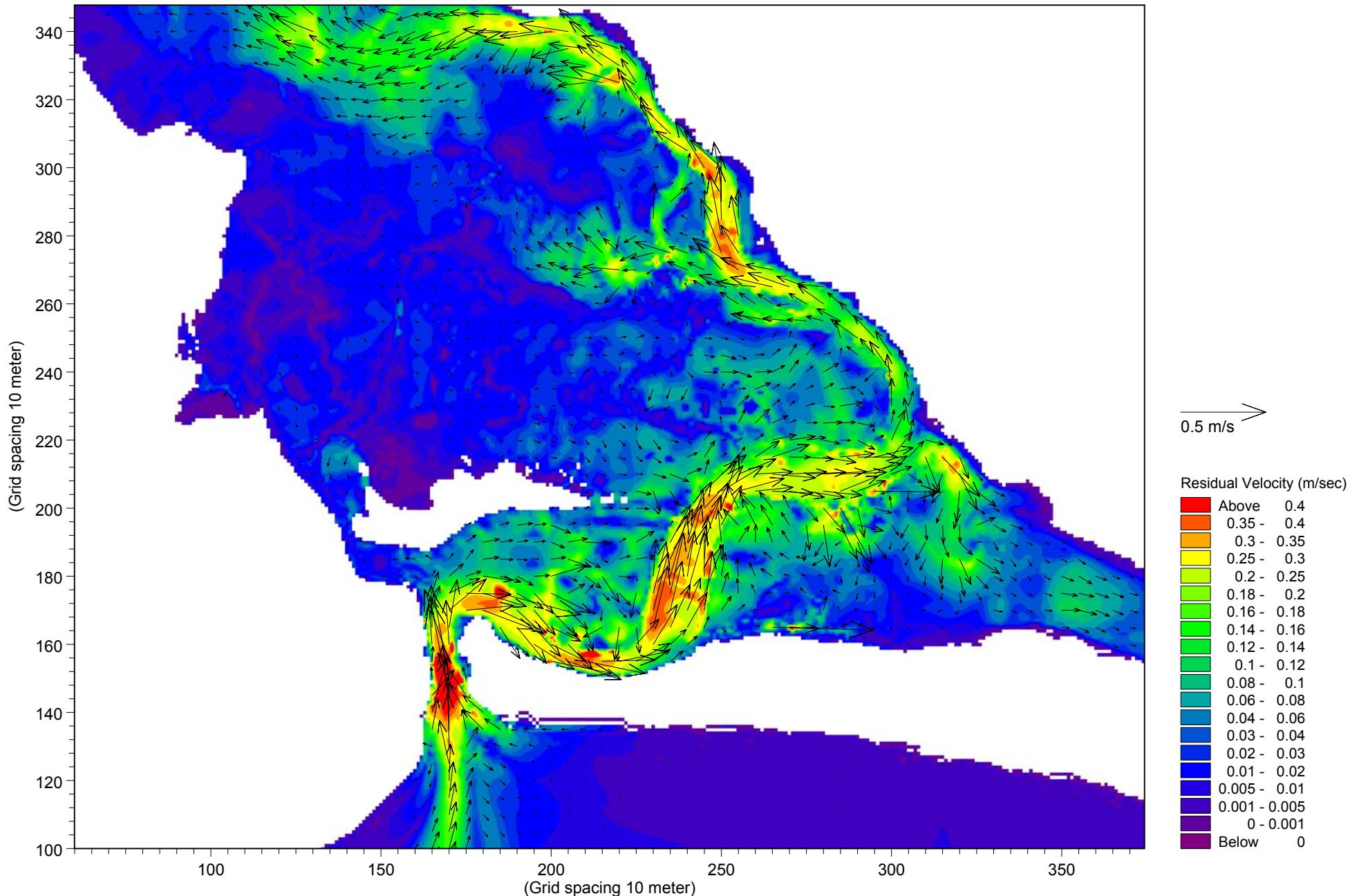


Figure 6.4d: Residual Velocities: Existing Conditions (1988) Scenario - Central Lagoon

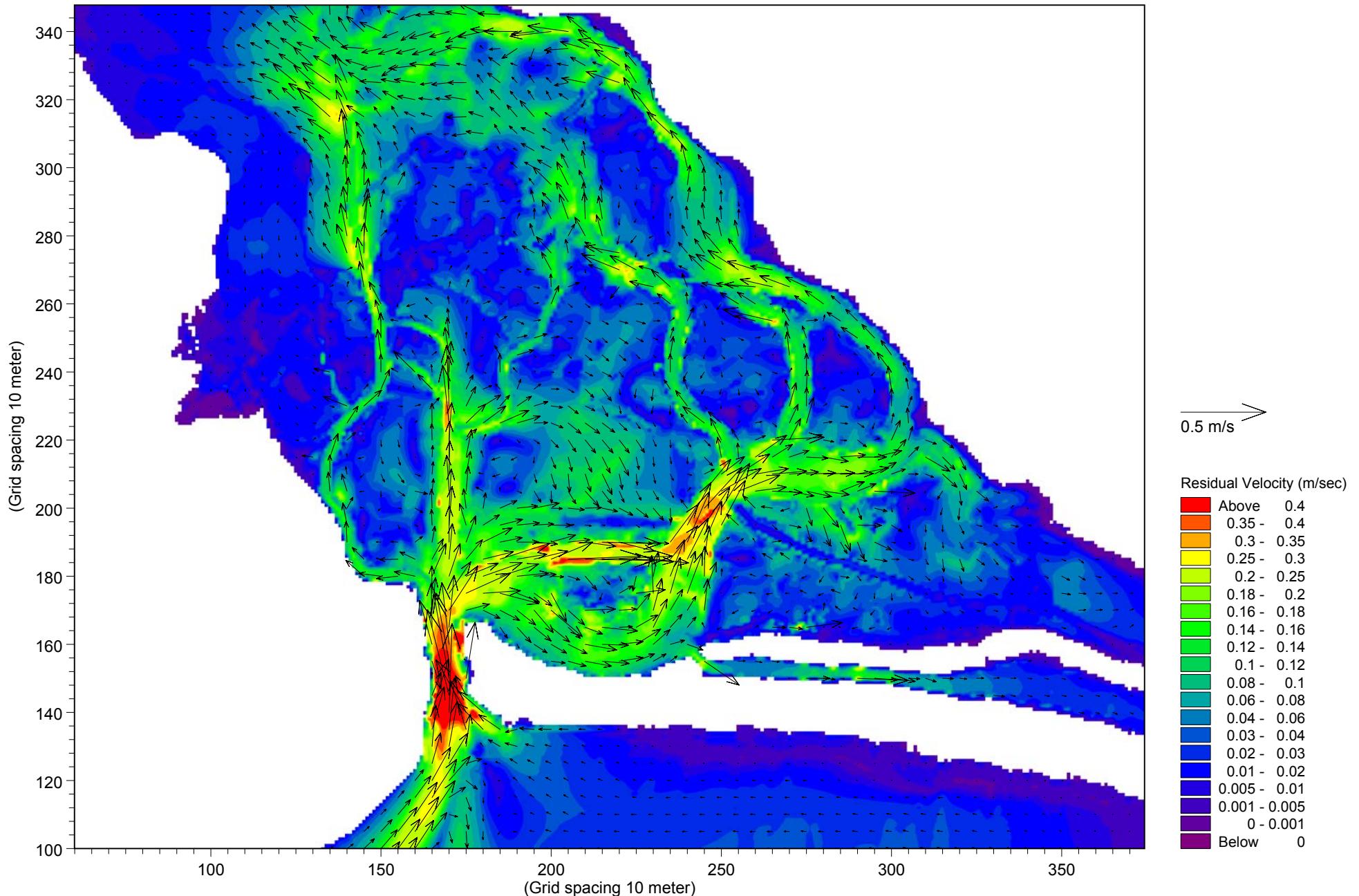


Figure 6.4e Residual Velocities: Full Construction Scenario - Central Lagoon

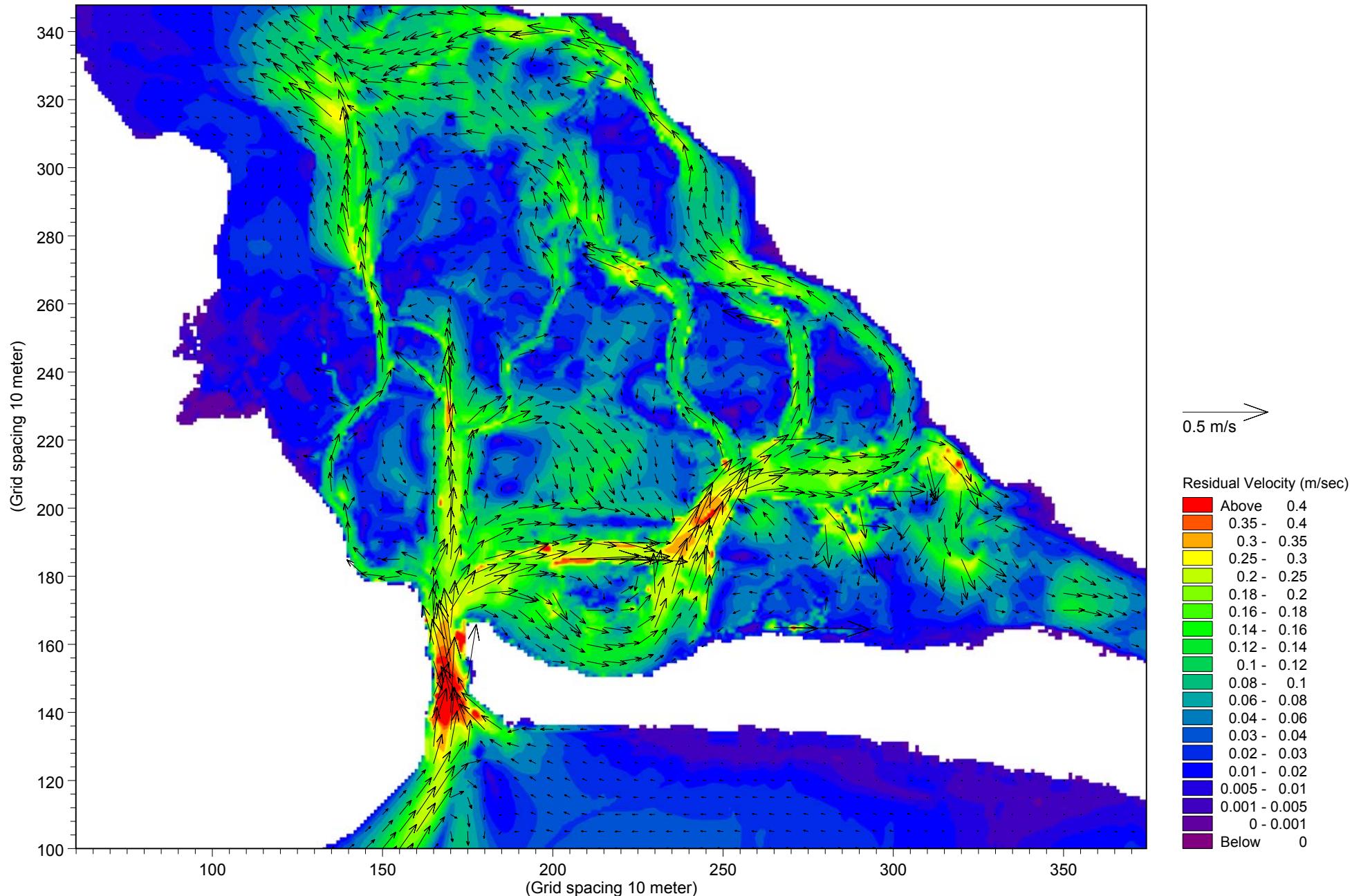


Figure 6.4f: Residual Velocities: North & Central Scenario - Central Lagoon

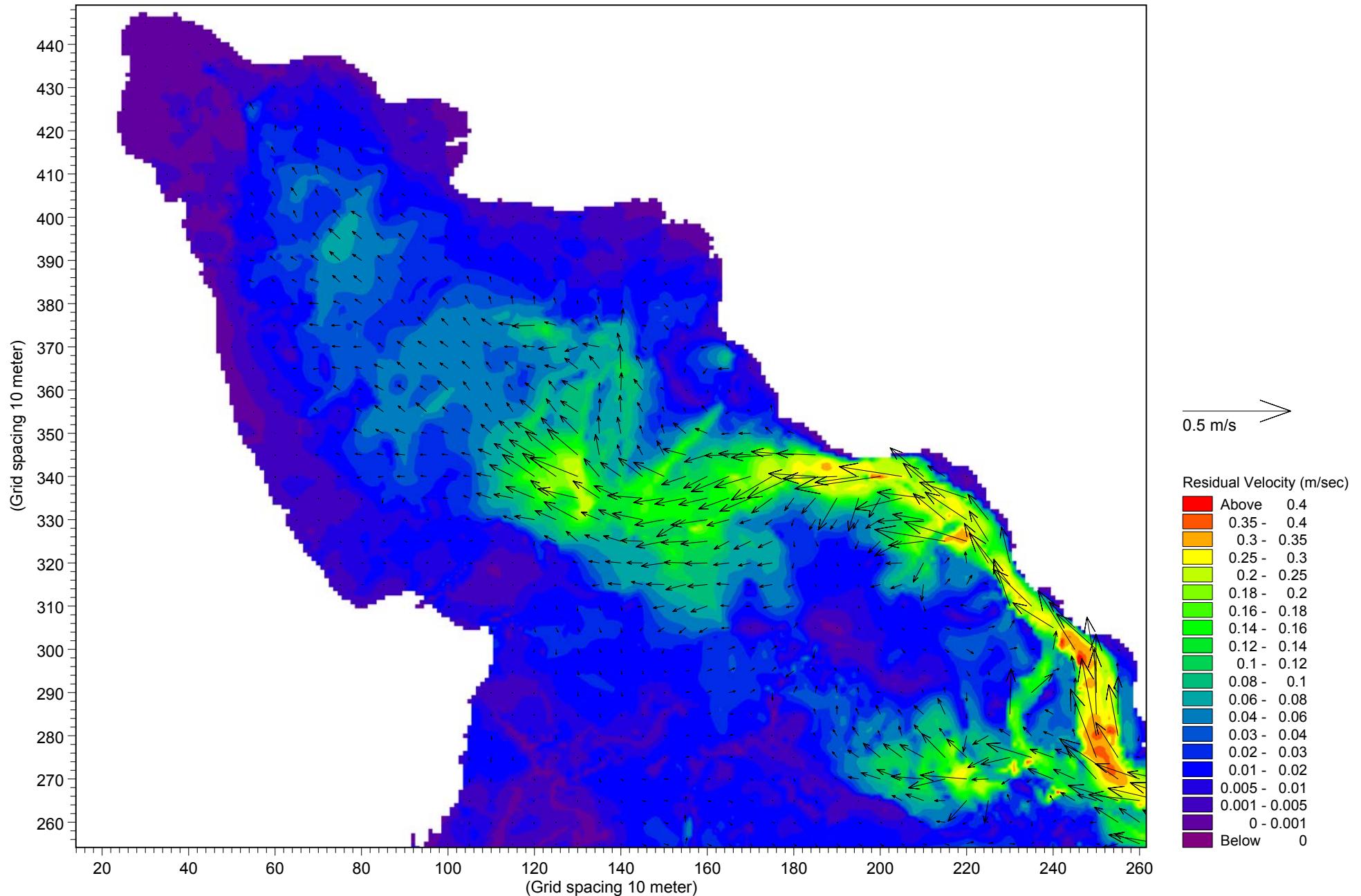


Figure 6.4g Residual Velocities: Existing Conditions (1988) Scenario - North Lagoon

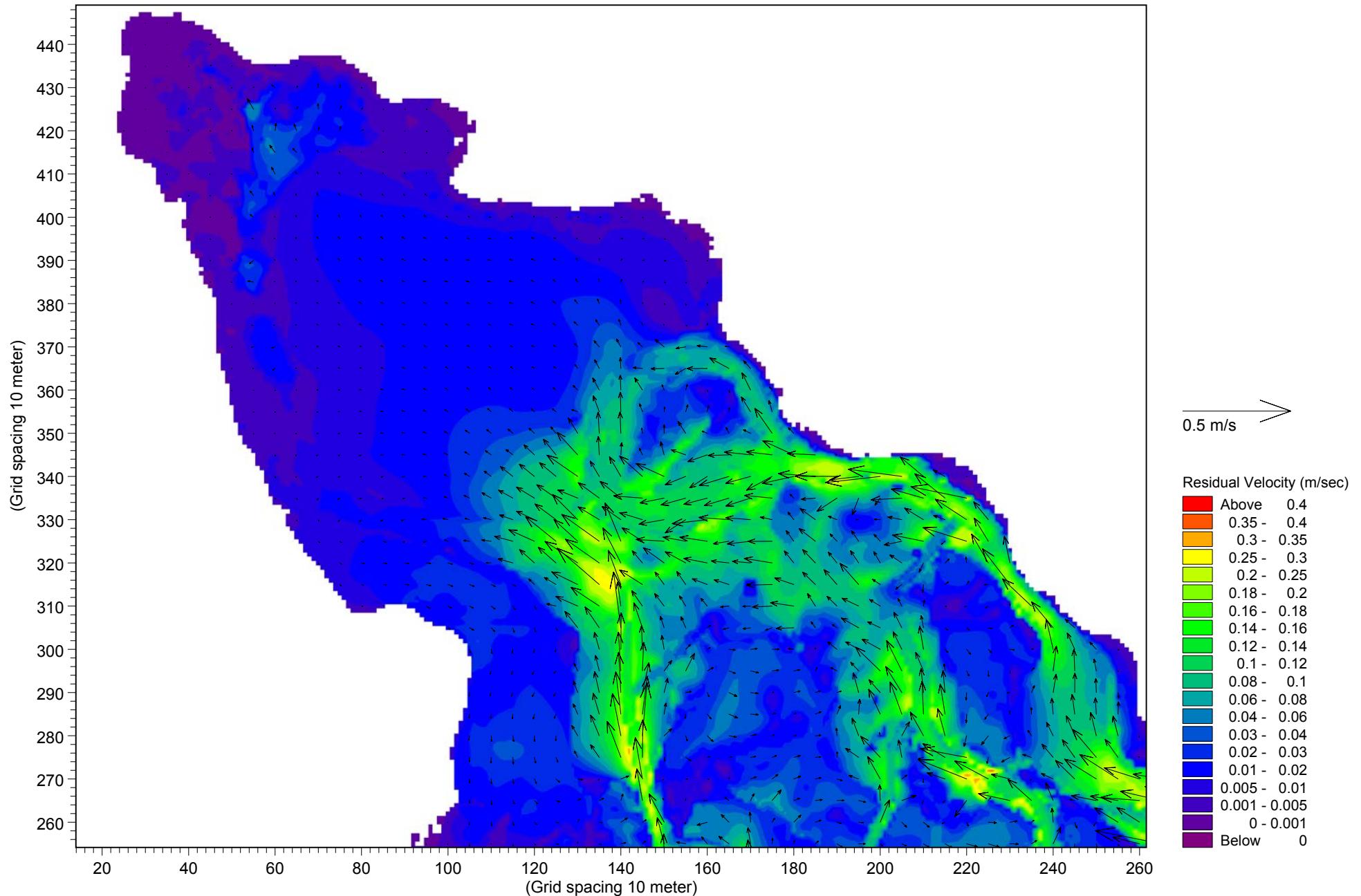


Figure 6.4h: Residual Velocities: Full Construction Scenario - North Lagoon

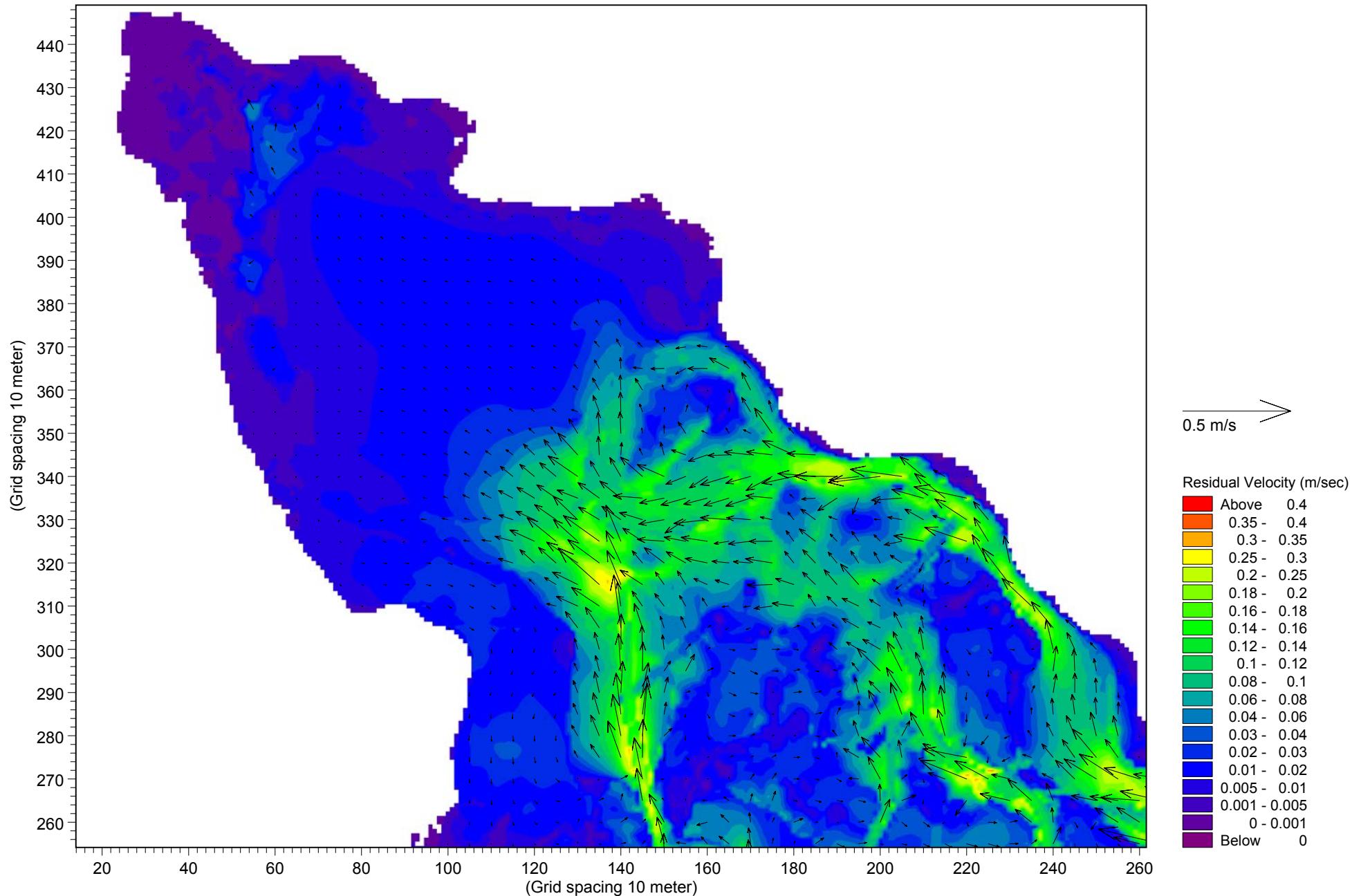


Figure 6.4i: Residual Velocities: North & Central Scenario - North Lagoon